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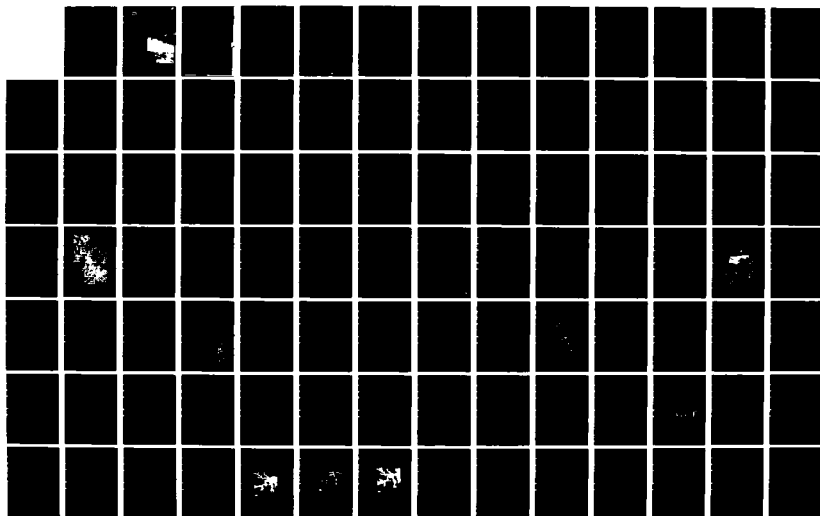
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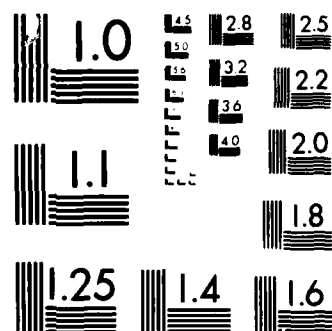
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US Army Corps
of Engineers
Kansas City District

Harry S. Truman Dam and Reservoir, Missouri

By Illinois State Museum Society
Springfield, Illinois

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Holocene Adaptations Within the Lower Pomme de Terre River Valley, Missouri

Volume I

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Excavations at Rodgers Shelter were conducted intermittently beginning in 1974 and ending 1976. The major work was completed in four summer field seasons, from 1964 to 1968. Excavations in excess of 9 m defined a sequence of human habitation that spans the past 10,500 years. Limited excavations were conducted in 1974 and 1976. The 1974 excavation dealt mainly with Phillips Spring. The 1976 excavation was part of the Corps of Engineers mitigation program for Rodgers Shelter, a National Register Site.			

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This report is a synthesis of the available knowledge gained from excavations and ancillary studies of the environment of the Ozark Highland/Southern Prairie Peninsula region. Data from previous studies are incorporated and assessed in light of new radiometric and stratigraphic controls for Rodgers Shelter and Phillips Spring. This research has altered, modified, and, on occasion, rejected previously held hypotheses, and has advanced ones of its own for future consideration. New information was collected that will allow for a re-evaluation of cultural process and taxonomy in this region.

Research reported includes historical vegetation reconstruction; ethnobotanical and faunal identification; clinal variation in gastropods and small mammals; examination of sediments; Holocene palynology; technological, functional and stylistic studies of major stone industries; and synthetic statements of site activity and activity areas.

The results of these often disparate studies promote a balanced view of how man existed for several millennia in a physiographically varied region that underwent considerable change of its own.

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HOLOCENE ADAPTATIONS WITHIN THE
LOWER POMME DE TERRE RIVER VALLEY, MISSOURI

edited by
Marvin Kay



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ABSTRACT

Interdisciplinary research centered on two lower Pomme de Terre archaeological sites, Rodgers Shelter and Phillips Spring, has dealt with the relationships between cultural adaptations and environmental change along the western flank of the Ozark Highland of Missouri for the past 10,500 years. Evaluation of previous investigations, principally of McMillan and Ahler, together with newly collected data allow a clearer understanding of these relationships as follows:

1. Early Holocene habitation by Dalton groups (circa 10,500 to 9,000? B.P.) at Rodgers Shelter was by small groups, probably by no larger a unit than a nuclear family, on an intermittent and sporadic basis. The fall of the year, and possibly the spring, were prime times of seasonal habitation, and large browsers such as deer and elk were hunted.

The landscape was very different from that of today, minimally consisting of a deeply incised valley with a more mesic forest cover than has since existed. Main sources of chert, used for chipped stone tools, were stream or river gravels, though later usage emphasized bedrock outcrops and hillslope residuum deposits. It is hypothesized that the upland landscape was mantled by loess and that hillslope bedrock exposures were few.

Subsurface investigations at Rodgers indicate that Dalton encampments were widely scattered along the floodplain, although the shelter may have served as a focus of occupation. We do anticipate that wherever insets of Terrace 1b exist that Dalton encampments may occur near the base of these deposits (6 to 9 m below surface).

2. Middle Holocene habitation (circa 8300 to 5100 B.P.) was to a changing landscape and climatic regime. Tall grass plains species occurred and were hunted sporadically. The Pomme de Terre rapidly aggraded, hillslopes were progressively denuded of vegetation and sediment, and climate became both warmer and drier than either before or since.

Concomitant change occurred in human settlement at Rodgers, which for several millennia served as a base camp for industrial (hematite and galena pigment processing) and other extractive and maintenance activities. Probably rude structures were erected on the Rodgers terrace and beneath the overhang; settlement may have been from fall through spring and, though intermittent, was on a sustained basis of weeks or months at a time. Population sizes may have increased but were aggregated in units no larger than a band of hunters and gatherers. The larger debris densities of the Middle Holocene Horizons 7 through 5 reflect the 3000 year period of sustained occupancy as much as they do a minimal increase in population sizes.

By 5100 B.P. Rodgers Shelter was completely abandoned due to the deposition on the terrace of coarse colluvium and alluvial fans derived from adjacent hillslopes, a geomorphic change local to toe-of-slope valley settings. We anticipate that settlement, circa 6300 to 5100 B.P., was in central valley locations, especially near perennial springs. Rodgers was not reoccupied until 3500 B.P. by late preceramic groups.

3. Late Holocene habitation by culturally similar preceramic groups (circa 4250 to 2500 B.P.) are first recognized at Phillips Spring about 4250 B.P., at Rodgers at 3500 B.P. and at Blackwell Cave by no later than 3100 B.P. As documented at Phillips, the most important change in subsistence activity revolves around an as yet understood adoption of horticulture of the tropical cultigens squash (*Cucurbita pepo*) and bottle gourd (*Lagenaria siceraria*). Gathering of native plant species and hunting and fishing, however, remained important as well. Differences in artifact assemblages, architectural features and plant food resources with known times of maturation and availability suggest functional differences in settlement type associated with (1) seasonal occupancy and (2) landscape or landform: shelter or cave sites appear as minimal specialized fall-winter encampments whereas open spring sites are more year-round horticultural base camps. Prepared human burials at Rodgers are further testimony of its specialized character.

4. Ceramic habitation (circa 2500 to 1000 B.P.) of valley sites continues to be dichotomized between open, spring horticultural base camps and specialized shelter or cave encampments. At Rodgers, the main activity indicators show a shift from game and plant food processing to game hunting, apparently during the fall and winter months.

On a taxonomic basis these final prehistoric habitations are divisible into three sequential units: (1) a Middle Woodland unit of a local Ozark Highland population adjusting to more distant sedentary populations of Hopewell villagers, (2) a local Late Woodland unit best defined by the Fristoe Burial Complex and selected technological items, and (3) an influx of partially contemporaneous Mississippian units, probably organized as small hunting parties from Stead-Kisker.

5. Climate and environment of the Late Holocene, circa 5000 B.P. to present, show a gradual return to more mesic, open forest conditions than existed during the Middle Holocene. Our greatest confidence in prediction of spatially defined biotic resources is for this period. But we anticipate that the immediately preceding interval witnessed a reduction in forest composition and contraction of forest to the main river valleys of the Pomme de Terre and Osage. In this riparian setting the vegetative mosaic so representative of the Ozark Highland apparently persisted during the Middle Holocene.

ACKNOWLEDGMENTS

This project has taken well over three years to complete and has involved the efforts of many people. To the crew members who worked on excavations at Rodgers Shelter and Phillips Spring, I wish to express my gratitude for their dedication and professionalism. Running those excavations were some of my most pleasant experiences, and much that made those summers memorable had to do with the fellowship expressed by the field crews. John Nylander and Bruce Benz, two field assistants who served in a variety of roles, deserve special mention. I wish to thank as well William H. Allen and Ronald Ward for assistance in deep site hydraulic coring operations, and their employer, the State of Missouri, Department of Natural Resources.

Jack Rodgers, the original landowner of Rodgers Shelter, has been a joy to know. He has been more than just a supporter of our research; he is our friend.

Others who have helped in more ways than I could adequately describe include W. Raymond Wood, Donald C. Johnson, Stanley A. Ahler and R. Bruce McMillan. It would be an understatement in any case to attempt to express my appreciation to these individuals in general and to Bruce McMillan in particular. The other authors of this report, who each assisted in phases of the field research as well as analysis, represent a cohesive team of specialists who have willingly cooperated and shared in this effort. It has been my privilege to have worked with and to have known them all.

The administrative assistance and professional attitude of Melvin A. Johnson, then of the Kansas City District, Corps of Engineers, are also acknowledged. His contribution to the project's success has not gone unnoticed.

Lastly, I wish to thank my wife, Susie, for her patience, understanding and support while this project was being completed.

PREFACE

Excavations at Rodgers Shelter were conducted intermittently for more than a decade, beginning in 1963 and ending in 1976. The major work was completed in four summer field seasons, from 1964 to 1968, during which a large block beneath and to the front of the shelter was excavated to bedrock. These excavations in excess of 9 m defined a sequence of human habitation that spans the past 10,500 years, and were completed under the direction of R. Bruce McMillan. Some of the results of these excavations were used by McMillan in 1971, in his Ph.D. dissertation "Biophysical change and cultural adaptation at Rodgers Shelter, Missouri," and, in 1976 were further reported in the volume *Prehistoric Man and His Environments: A Case Study in the Ozark Highland* edited by W. Raymond Wood and R. Bruce McMillan. As a product of this 1960's research, limited excavations were planned and conducted in 1974 and 1976, mainly to attempt recovery of small-scale remains and charcoal from selected strata and site subareas. These final two excavations were successful in meeting their goals, and were respectively completed under the directions of Kerry McGrath and me. The 1974 excavation was supported by a National Park Service contract that dealt mainly with Phillips Spring, a second lower Pomme de Terre site. The final excavation, in 1976, was completed as part of the Corps of Engineers mitigation program for Rodgers Shelter, because this National Register site lies within the conservation pool of Harry S. Truman Reservoir, Missouri. Subsequent excavation of Phillips Spring was also completed as part of the Corps of Engineers mitigation contract for Rodgers Shelter.

What is attempted in this report is a synthesis of the available knowledge gained from these excavations and ancillary studies of the environment of the Ozark Highland/southern Prairie Peninsula region. Data that were either unavailable or not developed by the previous studies are incorporated. As important, data previously examined are assessed in light of new radiometric and stratigraphic controls for Rodgers Shelter and Phillips Spring. The advances in dating and differentiating stratigraphic contacts at Rodgers Shelter have important ramifications for McMillan's interpretations of the Middle Holocene habitations of this site. In a complementary fashion, data on environmental and climatic processes allow modification of McMillan's and others' ideas on the dynamics of Holocene environmental change on the western flank of the Ozark Highland. Thus, it can be stated that this research has altered, modified, and, on occasion, rejected previously held hypotheses, and has advanced ones of its own for future consideration. It also can be said that new information has been collected that will allow for a reformulation of cultural process and taxonomy in this region.

The research reported covers a wide range beginning, in Chapter 2, with historical vegetation reconstructions and, in subsequent chapters, ethnobotanical, and faunal identification, clinal variation in gastropods and small mammals, examination of sediments, and Holocene palynology, technological, functional and stylistic studies of major stone industries, and synthetic statements of site activity and activity areas. Not all of this necessarily will interest every reader. But in dealing with such complex subjects as Rodgers Shelter, lower Pomme de Terre archaeology and Holocene environments, it was essential that a broadly-based, environ-

mentally grounded interdisciplinary approach be pursued. The results of these often disparate studies, however, promote a balanced view of how man existed for several millennia in a physiographically varied region that underwent considerable change of its own.

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CHAPTER 1

OVERVIEW OF THE MITIGATION PROGRAM

Marvin Kay

This report describes the mitigation program at Rodgers Shelter and Phillips Spring, two nationally prominent Pomme de Terre archaeological sites that lie within the conservation pool of Harry S. Truman Reservoir, Missouri (Fig. 1.1). By almost every measure this mitigation program must stand alone. The level of funding of slightly more than \$500,000.00, three year duration and interdisciplinary character of integrated cultural and environmental studies of two sites mark this as an unusual if not extraordinary project. This report answers the questions, "why" and "how" these resources were invested.

The logical place to begin this narrative is with Rodgers Shelter. Rodgers Shelter is the locus of some of the most thought provoking excavations in the Ozark Highland and, since 1966, it has been a catalyst for virtually all research in the Pomme de Terre River valley. The site is on the National Register of Historic Places. Its Holocene sediments, appropriately named "Rodgers alluvium," are now widely recognized in the Ozark Highland.

Rodgers Shelter is one of the deepest stratified sites in eastern North America. Its multilayered sediments in excess of 9 m contain an important Dalton and Archaic period sequence capped by comparatively thin deposits bearing Woodland period artifacts. Of equal interest, the site is a source of essential, albeit incomplete, paleoenvironmental information--a notable exception is pollen. Taken together, these two data sets illustrate prehistoric adaptations to an Ozark landscape that has undergone change of its own.

MCMILLAN'S MODEL

If one individual had to be picked, R. Bruce McMillan would be most easily, and justifiably, credited with the conduct of Rodgers Shelter research. This is not to minimize the contributions of W. Raymond Wood, Stanley A. Ahler, Paul W. Parmalee, or C. Vance Haynes; nor of the authors of this report. McMillan stands out because he completed the major excavations, systematically ordered its units in time and space, and formalized a model of the dynamics of cultural and environmental change at Rodgers Shelter (McMillan 1971, 1976). McMillan also helped shape this project. His statements about the relationships of past studies to Rodgers Shelter mitigation were in large part responsible for federal funding of the program as presented in our mitigation proposal (McMillan *et al.* 1975).

McMillan's model is developed from an "analysis of chronological variation" (McMillan 1976:212-223) and is in two parts. First, McMillan (1976:223-226) defines "changing patterns of human adaptation" at Rodgers Shelter. This is followed by a final section, "environmental change and cultural adaptation" (McMillan 1976:226-231) at Rodgers Shelter.

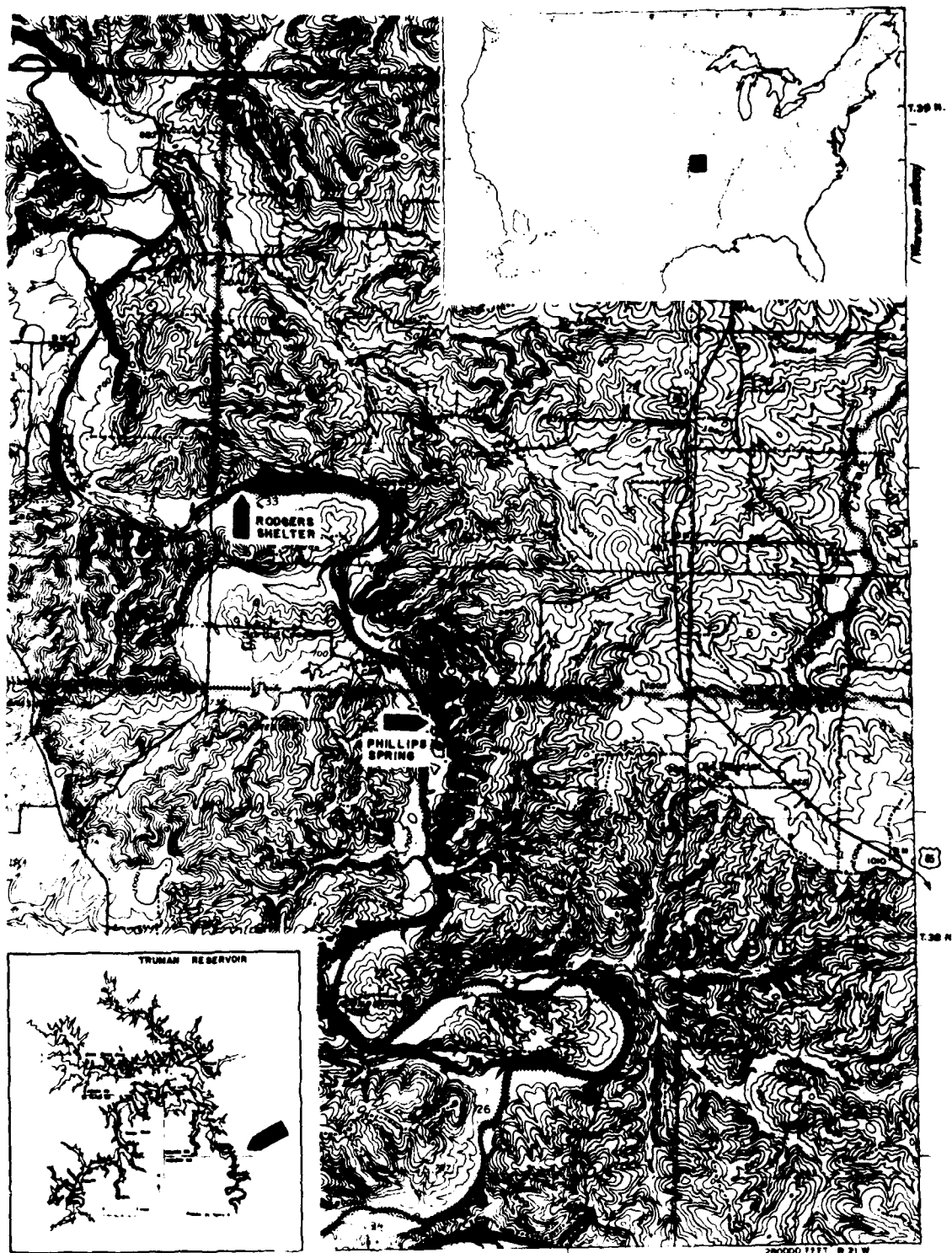


Figure 1.1. The lower Pomme de Terre Valley and studied sites. Conservation pool of Truman Reservoir is 706 feet above mean sea level.

McMillan's prime hypotheses are two. First, he posits that "there was a gradual shift during the mid-Holocene from a forest edge to a prairie biotype and back. It is believed that a vegetational change of this magnitude had a pronounced effect on the past human populations in western Missouri and accounts in part for the changes in subsistence and settlement strategies seen in the archaeological record" (McMillan 1976: 228-229). Second, McMillan (1976:229-230) submits: "The Rodgers Shelter sequence is instructive in that it is a case study for an area where changing paleoenvironmental conditions directly affected prehistoric food-procurement systems and settlement patterns during the mid-Holocene. During the earlier period, the Dalton horizon, the area was apparently forested and a wide range of plant and animal food was known.. .at Rodgers the occupations represent the remains of small transient bands."

He further contrasts the Dalton and subsequent Middle Archaic occupations by observing (McMillan 1976:230) that two variables, population increase coupled with a "deteriorating environment where increased incidence of severe drought was helping to transform much of the area's arboreal habitats to grass," resulted in long term use of Rodgers Shelter as a base camp (see McMillan 1976:224-225) where a wider range and greater number of activities occurred. At this time the site was occupied over long periods of the year (seasonally?) and for several centuries by related groups. He also notes that within the Middle Archaic there are changes in activity which are probably linked (caused?) to the environment: (a) a hunting procurement pattern that, while relying on small game, shifts through time from an early emphasis on squirrels to a later use of rabbits, other small rodents, and freshwater mussels; and (b) plant processing declined through time while industrial activities increasingly emphasized the processing of hematite pigment, using local raw materials. In general, however, hunting and butchering are conspicuous in the "significant lack of evidence" of their being major activities (McMillan 1976:224-225), seemingly this corresponds with a decline in the frequencies of deer remains relative to other time periods. Finally, the Middle Archaic ended with "the virtual abandonment of Rodgers Shelter after 6300 B.P. for 3000 years" (McMillan 1976:230). This coincides with the deposition of a 1 m thick coarse alluvial fan onto the Rodgers terrace (Terrace 1b; Haynes 1976). McMillan (1976:230) cautions that "it is unknown whether there was merely an adjustment in the local settlement system that excluded Rodgers Shelter or whether the entire area was abandoned."

In any event, the reoccupation of Rodgers Shelter some 3000 years later by Late Archaic groups coincides with "a return to environmental conditions supporting deer herds and, concomitantly, to a procurement system designed to exploit these animals. There was also increased use of aquatic resources, although it is not known if this is related to changes in the stream itself following the hypsithermal." (McMillan 1976: 230). Other sites in the vicinity by 2700 B.P. appear to be functionally different from the Rodgers Shelter settlement, as they contain structural or architectural remnants such as pits and postmolds. At Rodgers Shelter these features are not seen, though there is evidence of ritual or ceremony in the form of two prepared burials.

Interpretation of the subsequent (and terminal) Woodland occupations

is hindered by mixing of Woodland and Late Archaic materials and the limited presence of diagnostic Middle Woodland pottery (McMillan 1976: 226). Nonetheless, the Late Woodland artifacts are assigned to the Fristoe burial complex, defined by Wood (1961, 1967). McMillan (1976: 231) hypothesizes and goes on to observe that: "The Late Woodland occupation represents a new level of organization. Rodgers Shelter is believed to have served as a hunting and fishing camp for peoples who have been described as semisedentary horticulturalists (Wood 1976:125). We are not certain how early cultigens reached the area; presently there is evidence from Boney Spring...for domestic squash (*Cucurbita pepo*)... at 1900 years ago."

McMillan did an admirable job of sorting through a mass of diverse information and of presenting his conclusions in a coherent and largely convincing fashion. This is not to say that nothing else was required of the subject of Rodgers Shelter. Indeed, in reviewing these conclusions we (McMillan, Ahler, and I) were basically of two minds. First, we felt that there was a real need to evaluate all of the data from Rodgers Shelter. Or, if this proved impossible, at the very least to examine the major classes of finished artifacts and tools, to review their geomorphic and stratigraphic contexts, and their configurations in space--the latter in attempts to define "macroactivity areas" insofar as these could be interpreted without reference to architectural features. Second, we realized that sampling would be needed to further examine ideas on chronology, environmental change and subsistence at Rodgers Shelter. As illustrations, there were no radiocarbon dates for the Late Archaic and Woodland units of Rodgers Shelter, the affects of an unconformity dated about 7500 B.P. on debris distributions and densities were unknown, diachronic change in artifact style had not been explored, and there were gaps in the subsistence and environmental records.

This project tests McMillan's model. We do this by (i) the further examination of major classes of debris excavated from Rodgers Shelter and (ii) the analyses of new data from this and other lower Pomme de Terre sites, primarily from Phillips Spring. It should come as no surprise that we have modified, refined, restated and/or rejected parts of McMillan's model. We do not look at this as any more than a logical outcome of several more years of intense study that included limited excavation of Rodgers Shelter and large scale block excavation of Phillips Spring. At times, however, the results surprised even us.

RODGERS PROJECT MITIGATION

Our philisophy is that mitigation in the case of Rodgers Shelter is to developpe the maximal information potential for the kinds of data the site can contribute to the understanding of culture process and human adaptation. Correlated efforts, as at Phillips Spring, are to be integrated through the systematic collection, analysis and perpetual curation of site materials, records and reports that insure the conservation of archaeological information in a secondary context. Insurance of the maximum information potential of archaeological resources is, in our view, the crux of mitigation: The mitigation program for Rodgers Shelter and Phillips Spring is one that should be consistent with contemporary standards of archaeological method and theory, have a rigorous research

design, and attempt to further define those cultural processes through which societies articulate with the natural environment and other cultural systems. The goal is to model cultural adaptations within the lower Pomme de Terre in as complete a fashion as our data allow.

We submit that the key to modeling cultural adaptation is the understanding of external constraints and systemic responses that keep a culture in balance, or to one degree or another, lead to a new systemic state. This task is compounded by the normal vagaries of archaeological data (Schiffer 1972) that make seeking homeostatic mechanisms particularly onerous though the search can be idealized as a simple process. Ashbey's (1965, cited by Clarke 1968:59) notion of a Black Box, a complex system knowable only through its input and output terminals, is appropriate to archaeological theory. At the risk of regarding a culture system in the way of the parable of the blind men and the elephant, the understanding of archaeological data is, and always will be, a simplification. But, it is hoped, one that leads to more general principles about our human condition. Knowledge of cultural systems has been most closely approximated by their stylistic, technological or extractive aspects, particularly as these relate to subsistence or settlement. Though these are traditional concerns, it has been only recently that the broad outlines of North American prehistory (Willey 1960, 1966; Griffin 1967) have emerged. As Binford (1964) phrased it, we are mainly answering the "what," "when" and "where" questions about cultural systems and are beginning to ask "how" and "why" as well.

The need for regional planning to develop data requirements and research strategies has been forcefully expounded upon by others (Binford 1964; Struever 1968, 1971) and, it is clearly illustrated by this Pomme de Terre archaeological program. We should expect that hunting and gathering societies, whose remains are our primary data base, would articulate closely with the natural environment. For instance, a differential spatial configuration and/or seasonal availability of desired food resources might be directly related to the overall placement of settlements or their seasonal usage for a particular locality. Similarly, fluvial systems might bear directly on site size, function or season of use because of variation in the rank order of streams, their periodic flooding or seasonal drying. As a consequence of these and other factors, no single site should be regarded as more than a component of a larger system. To paraphrase Caldwell (1964:135), the achieved resolution of cultural systems is proportional to the amount of effort spent in a systematic, multisite--and often interregional--investigation of its constituent components.

In dealing with a single site, Rodgers Shelter, there is a recognized bias that only in part (cf. Wood *et al.* 1976) is controlled for through the parallel research at Phillips Spring. Nevertheless, these are functionally contrastive sites of culture complexes of the Ozark subarea (Willey 1966:249). Additionally, many of the data requirements for paleoenvironmental reconstructions are met at one site or the other. Particularly, the pollen and plant macrofossils from Phillips Spring are expected to afford our best resolution of Holocene vegetation.

Respective to Rodgers Shelter, Phillips Spring research is in a preliminary phase. Modification of some of the conclusions presented here will be made as the Phillips Spring data are developed.

RESEARCH DESIGN

With few modifications, the proposal submitted to the Corps of Engineers, Kansas City District (McMillan *et al.* 1975) has served as the blueprint of the studies summarized in this report. What revisions have been made accurately reflect the realities of conducting a multi-year research effort. Avenues have been followed that promise to meet our goals. Others have proved to be either dead end or beyond this project's time frame and resources to pursue; an example of the former is the attempt to model prehistoric animal populations, particularly those of prime economic importance, for the Truman Reservoir area; the latter, the experimental chipped stone tool manufacture, debitage and wear studies. Though certain studies have proved impractical, the tenor of the research has remained true to the original design.

Rodgers Shelter and Phillips Spring research includes the refinement of absolute (radiometric) chronologies, delineation of stylistic indices for temporally distinctive artifacts, and tests of models of changing cultural adaptations, initially developed at Rodgers Shelter, through further sophisticated sampling techniques. These efforts are not only essential to any meaningful attempt at site mitigation, but also are of value to other research efforts in Truman Reservoir.

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CHAPTER 2

VEGETATIONAL RECONSTRUCTION AND PLANT RESOURCE PREDICTION

Frances B. King

INTRODUCTION

In response to climatic changes the vegetation of the western Missouri Ozarks has changed during the past several thousand years in ways which have significantly altered the potential plant and animal resources of the area. Pollen records indicate "spruce with deciduous elements" as recently as 13,000 years ago (King 1973). Since the disappearance of spruce, oak and hickory species have dominated the forest composition. However, during the early postglacial (Holocene) period, this oak-hickory forest may have been more mesic (moist) than the modern forest of the area which resembles it in composition but seems to have a somewhat lower tree density. By 8000 years ago, the climate had become sufficiently warm and dry so that forest diminished and was replaced by the herbs and grasses more characteristic of the prairie.

This trend toward climatic warming reached its maximum at about 7000 B.P. and started to return to more favorable climatic conditions about 4500 B.P. (King and Allen 1977). Throughout the Holocene, as undoubtedly in other times, the overall regional vegetation was determined by climate (most importantly, the interaction between temperature and precipitation), while the local vegetation was strongly influenced not only by climate, but by geological factors including soil, bedrock, topography, aspect (direction a point is facing), slope, and other factors such as storms, fire and man.

CLIMATE

The Truman Reservoir lies in the "Prairie Peninsula" (Fig. 2.1) (Transeau 1935), a wedge-shaped region extending from the Rocky Mountains to Indiana, where the growth of grasses and other short season, deeply rooted or drought tolerant herbaceous species is favored over that of woody species by a lower annual and seasonal precipitation/evaporation ratio, lower midsummer relative humidity, more irregular precipitation in terms of annual amounts, seasonal variability and spatial distribution (Transeau 1935). Prairie, once established, will prevent the encroachment of forest by shading, by superior water utilization, and by forming such a dense sod cover that tree seedlings cannot get established. Such grass dominated communities can exist on a large scale only within a favorable climatic regime. Towards the humid eastern border of the prairie, conditions tolerable to both grasslands and forest exist. In these ecotonal regions, such as the one in which the Truman Reservoir lies, certain soils or topography may favor the establishment of either forest or prairie (Curtis 1959:302). Also, in these areas, fire favors the persistence of prairie, since tree seedlings are generally more fire susceptible while most prairie species have extensive underground root

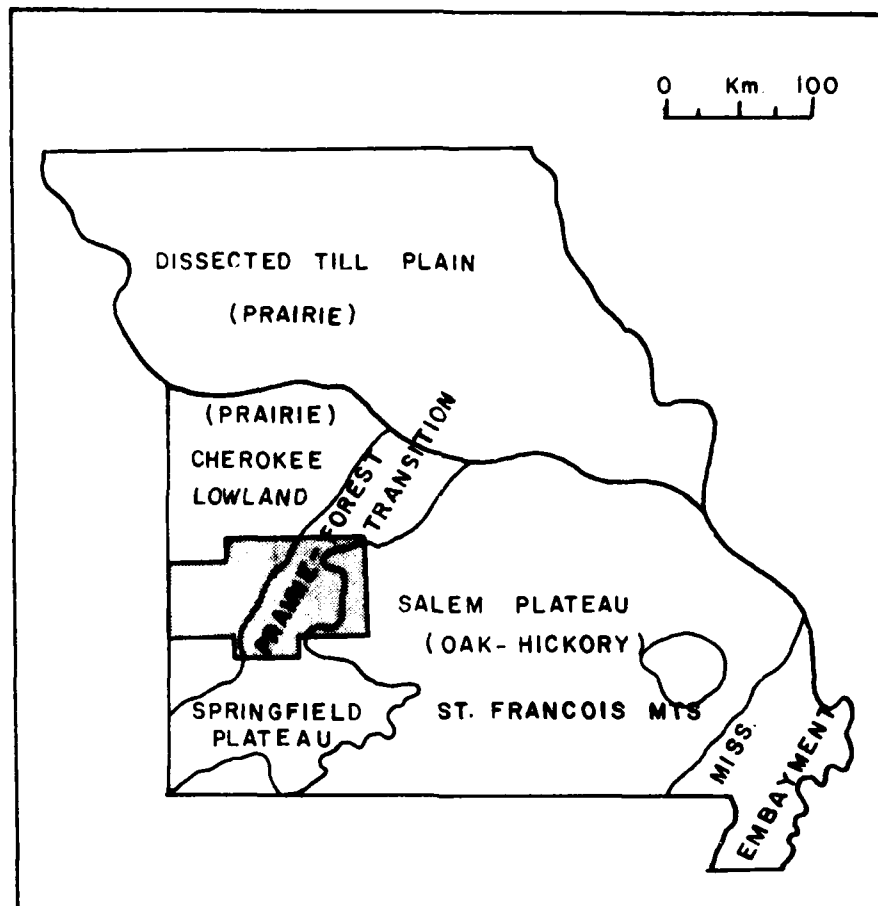


Figure 2.1. The Truman Reservoir in relation to physiographic sub-provinces (after Bretz 1965) and natural vegetation (after Fig. 1.1).

systems which are less affected by periodic rapid burning of the dried above ground portions.

BEDROCK

The Truman Reservoir lies on the western edge of the Ozark Highland (Fig. 2.1), a structural dome that is one of the oldest land areas in the United States (Bretz 1965). Because of the uplifting which has occurred in the Ozarks, the bedrock structure of the area is characterized by the west-northwestward dipping strata, with the older portions outcropping on the east (Ward and Thompson 1977). Four major types of rock occur within the Truman Reservoir area: from east to west (oldest to youngest) these are: 1) Ordovician age dolomite (Gasconade), sandstone (Roubidoux) and sandy, cherty dolomite (Jefferson City, Cotter); 2) Mississippian age limestone and cherty limestone (Burlington); 3) lower Pennsylvanian age shale and sandstone with some limestone and coal (Cherokee group); and 4) upper Pennsylvanian age shale and limestone with some sandstone (Ward and Thompson 1977). The southeastern half of the Truman Reservoir is predominately underlain by limestone and dolomite. Because these rocks are readily dissolved by groundwater, there exists a well developed surface and subsurface drainage as well as steep relief. Because of internal drainage, permeability is also high. Residual materials are composed of undissolved clay, sand, and chert nodules. The northwestern half of the reservoir is underlain by shale, clay, or sandstone which are not generally so subject to dissolution. Surface runoff is greater in this area because of the lack of subsurface drainage systems and because residual material is often thin.

Topography, water holding capacity, and subsurface permeability are important factors in determining the type of vegetation an area can support. Grasses have dense intensive root systems which penetrate a small volume of soil. They grow best on finely textured soils which allow greater root penetration. Trees, on the other hand, have extensive root systems which not only grow around rocks, but can penetrate deeply into bedrock cracks. Woody plants dominate a plant community on rocky soils, even when subjected to impoverished precipitation regimes (Walter 1973:71). Rain falling on coarse textured soil penetrates almost immediately so that less is lost through surface runoff with the result that forests extend farthest into arid regions when coarse soils are present (Daubenmire 1959:18). Grasses outcompete trees in situations where there is a shallow soil overlying some impenetrable surface, such as unfractured bedrock or heavy clays. In these situations, surface runoff is rapid and results in adequate enough moisture to support plant growth for only a short period. There are numerous prairie species, mostly grasses, which have a short, early spring growing season as an adaptation to these situations. By the time the soils are dried out, the grasses have grown, flowered and set seed. Trees have a much longer growing season. When trees are found in particularly dry situations, they either are tolerant species or they are exploiting a special microenvironment, such as a bedrock seep (Daubenmire 1959).

In ecotonal climates, prairie generally occurs on the level surfaces where the soil is well developed, uneroded, and fine grained. In addition, grasses are more capable of tolerating the sun and wind desiccation

characteristic of such exposed areas. Trees grow best on slopes and in valleys where they are protected from desiccation and where the soil is likely to be coarse and rocky because the smaller particles have been carried downslope, and because erosion breaks the sod, enabling tree seedlings to become established (Daubenmire 1959).

The distribution of slope categories by bedrock types in Benton County reflects to a degree the potential distribution of forest and prairie. The western part of the county underlain by sandstones and shales had 60% of the points in the 0-2% slope category and another 20% in the 2-5% slope category, while the area underlain by Burlington limestone and Jefferson City dolomite is intermediate, with approximately 30% of the area in the 0-2% slope category, but still dominated by relatively gentle slopes, while the Gasconade and Roubidoux formations of eastern Benton County have slopes of mostly greater than 5-9%. On the basis of soils and slopes, we would predict that the flatter lying areas would be primarily prairie and that there would be increasing amounts of forest to the east, which is the case for both the presettlement and modern vegetation (Fig. 2.1).

RECONSTRUCTION OF ORIGINAL FORESTS: THE G.L.O. SURVEYS

However detailed the collection and analysis of cultural remains, understanding subsistence-settlement patterns or changes in them requires familiarity with the environment. Our goals in this project are to model spatio-temporal changes in biotic resource availability and to compare these models to information from archaeological sources.

An historic baseline for this study is the reconstruction of the vegetation as it was just prior to settlement in the early 1800's. During that period, the federal government General Land Office (G.L.O.) in anticipation of the westward migration of pioneers, subdivided the land into legal township units of six miles on a side, later divided into 36 sections each one mile square. At each half mile (quarter section) and mile (section corner) point along a line, the surveyors would blaze two (quarter section) or four (section corner) trees with the survey data, one tree in each section. They also recorded the species, diameter, distances, and bearing to each tree, thus producing vegetation data which, while not sampled in a perfectly random manner, were at least sampled by a procedure resembling that of the modern transect methods of the ecologist (Cottam, Curtis and Hale 1953; Curtis 1959; Bourdo 1956).

One or more types of bias were frequently introduced in surveying. Sometimes, more easily blazed tree species were selected over those with thick bark or dense branches. Trees too small to carry the necessary information (less than 4") and large, old trees that might die soon were also avoided. Frequently the distance to, or the diameter of a tree were approximated rather than measured (Bourdo 1956, Hushen *et al.* 1966). Species bias can render the data from the surveys useless for reconstructing forest composition and several methods have been used to test for this type of bias. These methods are based on the rationale that in a stand in which the tree species are randomly distributed, the mean distance from the survey point to each common species should be the same and only the frequency should vary depending upon species density (Bourdo 1956). Distances recorded by the G.L.O. surveyors for Benton County were found to have insignificant bias when checked either by Chi-square (Bourdo

1956) or Analysis of Variance (Delcourt and Delcourt 1974) methods.

The environment has changed a great deal since the first settlers moved into the Midwest. It was probably considerably disturbed even earlier by aboriginal activities including burning, firewood collection, and agriculture (Day 1953). Day states: "It appears probable that early writers saw only a small part of the agricultural clearing in the northeast. Fields were abandoned as they wore out or as white settlements came close. These abandoned fields grew up to forests." The surveys were also made at a time of cooler, moisture climate (Wood 1976b) and frequent periodic burning (F. King 1978, Loucks 1970, Wells 1970). Both factors probably acted to change the composition and distribution of the presettlement forest. Despite all of the problems inherent in the use of the G.L.O. survey data, they have been widely used in the past and will continue to be used in the future, because in most places, they are the only information available about biotic communities which have long since vanished.

SAMPLING

The Truman Reservoir lies on the forest-prairie ecotone and encompasses the numerous types of soil, bedrock, and topography discussed above, and it was desirable to map the presettlement vegetation of the entire reservoir area for use in the archaeological surveys. However, it was not necessary to study the entire reservoir in detail for correlation with environmental factors or in building vegetational models since a section of the reservoir could be chosen that would form a transect across almost all of the different bedrock and soil types. This sampling area includes 500,000 acres in Benton and northern Hickory counties as well as the area around Rodgers Shelter and was chosen because it lies on the forest-prairie transition zone. For each quarter section and section corner point in this area the following information was recorded from the survey records: township, range, section, species, diameter, bearing, distance, surveyor, month and year; from topographic maps: landform, elevation, aspect, slope, and stream rank. Information was read from microfilm copies of the survey notes, coded and computer analyzed for a total of 1996 points. Detailed soil information is not available for the study area and bedrock was used as a gross indicator of soil type. Information was punched directly onto computer cards from these coding sheets and analyzed using various statistical routines.

RESULTS

A map of the presettlement vegetation of the Truman Reservoir is shown in Figure 2.2. As has already been discussed, the distribution of forest and prairie in this map is strongly influenced by environmental factors, not only by climate, but by bedrock, soil, and topography. Data were collected for a total of 1996 points, of which 1252 had at least two trees. Table 2.1 lists the species names (following Stevermark 1963), the common names, and the relative frequency of the trees recorded for Benton County, Missouri. The dominant tree species include black oak, white oak, and post oak. Other common taxa include blackjack oak, black walnut, hickory, red oak and elm. The dominance of oak and hickory

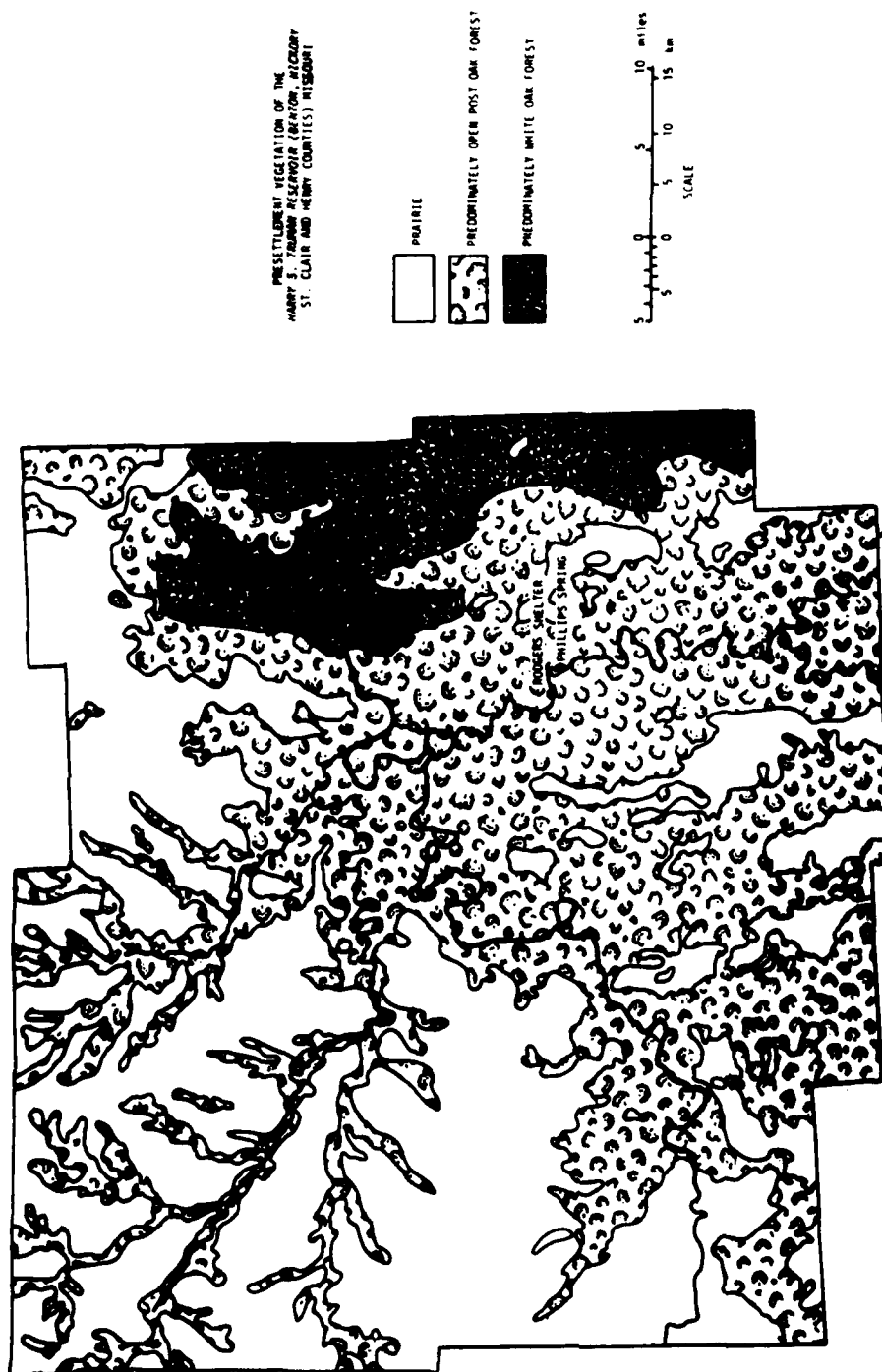


Figure 2.2. Presettlement vegetation of the Truman Reservoir.

TABLE 2.1

Distribution of Presettlement Forest Species by Landform, Benton County, Missouri

Species	Bottomland	Slope	Barrens	Upland	Prairie	Total
Post oak (<i>Quercus stellata</i>)	7.9%	32.2%	53.6%	42.9%		
Black oak (<i>Q. velutina</i>)	15.3	23.9	19.1	17.6		
White oak (<i>Q. alba</i>)	14.1	24.7	8.3	14.3		
Blackjack oak (<i>Q. marilandica</i>)	1.2	5.8	2.4	12.1		
Bur oak (<i>Q. macrocarpa</i>)	15.3	0.7	---	2.2		
Red oak (<i>Q. rubra</i>)	0.6	1.1	---	3.3		
Chinkapin oak (<i>Q. prinoides</i>)	1.2	1.6	1.2	---		
Pin oak (<i>Q. palustris</i>)	4.9	2.1	2.4	2.2		
Water oak (<i>Q. bicolor</i>)	2.5	0.2	2.4	---		
S oak (<i>Q. imbricaria</i>)	---	---	---	1.1		
Oak (<i>Quercus</i> spp.)	---	---	---	1.1		
Black hickory (<i>Carya lucana</i>)	0.6	0.2	4.8	---		
White hickory (<i>C. tomentosa</i>)	---	0.1	---	---		
Shagbark hickory (<i>C. ovata</i>)	---	---	1.2	---		
Hickory (<i>Carya</i> spp.)	6.2	4.2	3.6	2.2		
Pecan (<i>C. illinoensis</i>)	0.6	---	---	---		
Black walnut (<i>Juglans nigra</i>)	4.3	0.5	1.2	---		
Butternut (<i>J. cinerea</i>)	---	0.1	---	---		
Elm (<i>Ulmus</i> spp.)	9.8	0.8	---	---		
White elm (<i>U. americana</i>)	2.5	---	---	---		
White ash (<i>Fraxinus americana</i>)	1.2	0.1	---	---		
Ash (<i>Fraxinus</i> spp.)	1.2	0.4	---	---		
Hackberry (<i>Rhitis occidentalis</i>)	1.8	---	---	---		
Honey locust (<i>Gleditsia triacanthos</i>)	0.6	---	---	---		
Sycamore (<i>Platanus occidentalis</i>)	4.3	---	---	1.1		
Persimmon (<i>Diospyros virginiana</i>)	---	0.1	---	---		
Red cedar (<i>Juniperus virginiana</i>)	0.6	0.1	---	---		
Sugar maple (<i>Acer saccharum</i>)	0.6	0.2	---	---		
Maple (<i>Acer</i> spp.)	0.6	---	---	---		
Cherry (<i>Prairae</i> spp.)	0.6	---	---	---		

TABLE 2.1 (concluded).

Species	Bottomland	Slope	Barrens	Upland	Prairie	Total
Basswood (<i>Tilia americana</i>)	0.6	0.2	---	---		
Total	99.1%	99.3%	100.2%	100.1%		
Total Number of Species	25	21	11	11		
Percent	12.3%	44.0%	7.0%	4.8%	31.6%	99.7%
Acres	58,410	208,947	33,241	22,794	150,062	473,454
Hectares	23,647	84,594	13,458	9,228	60,753	191,680

species reflects the nature of the forests of western Missouri as depauperate outliers of the eastern deciduous forest. Almost all characteristic eastern deciduous forest species occur in the Ozarks but many are extremely limited in distribution.

The majority of the quarter section and section corners in Benton County at the time of the G.L.O. surveys were forested (80%), while prairie and barrens each occupied about 10%. The most common landform was slope (73%), followed by bottomland (17%), and level uplands (10%). Only 10% of the points in the 0-2% slope category were forested, while 97% of those in the 14+% slope category were.

FOREST DENSITY

The G.L.O. surveyors measured the distance and bearing of each witness tree from the section corner and quarter section points, and several methods have been developed to use this information for calculation of tree density. The relative value of the various methods depends on the number of trees at each point. All are based on the assumption that the distribution of trees in a forest deviates at random from a theoretical condition in which all the trees are equidistant from the adjoining trees (Cotton and Curtis 1949, 1956) and each tree dominates a hexagonal area bounded by the areas of the neighboring trees.

Presettlement tree density for Benton County is low regardless of how it is calculated and is less than 15 trees per acre in bottomland, 20 trees per acre in slope and upland forests. In comparison, Anderson and Anderson (1975) found 6.4 trees per acre in the savannah and 64.7 trees per acre in the forest in southern Illinois. Wuenscher and Valiumas (1967) found between 36.8 and 70.8 trees per acre for five counties in the River Hills region of central Missouri with an average of 53.5 trees per acre in a white oak forest. Modern forest density is considerably higher, often exceeding 200 trees per acre in mesic habitats (Rochow 1972) or 100 trees per acre in the more xeric western Missouri Ozarks. Presettlement tree density for bottomland and upland forest vary little with the method. However, density of barrens varies greatly, from 16 trees per acre for the point quarter method, 19 for the random pairs method, to 1 tree per acre for the closest individual method. There are sufficient numbers of sample points (Cotton and Curtis 1956) that the very low density calculated by the closest individual method is probably most reflective of the nature of the "Barrens."

Virtually every study of presettlement vegetation has found a large disparity between presettlement and modern forest density. It is usually accompanied by a composition difference as well since the most obvious cause for changes which have occurred since settlement is the cessation of periodic burning (Kuehler 1974, Rice and Penfound 1959, Howell and Kucera 1956, Beilman and Brenner 1951).

DIAMETERS

It is possible to tell something of the history of a forest by its size structure. In mature, undisturbed forests, the smallest diameter classes are most highly represented and tree frequency falls off with increasing age and size (Bourdo 1956, Johnson 1974). A forest that has

been disturbed within the preceeding several hundred years will have many trees about the same age, since a large number of seedlings, which otherwise would have a high mortality, would have survived.

There was considerable bias toward the selection of trees with certain diameters by the G.L.O. surveyors since they wanted trees large enough to blaze but young enough to potentially stand as witness trees for a long time. Also, tree diameters were often estimated, especially for larger trees. For these reasons, there is an over representation in the land survey records of trees in the twelve inch diameter class, and to a lesser degree, in the ten and fourteen inch classes. The eight inch, six inch and four inch trees were increasingly under represented as were the very large diameter classes (Bourdo 1956). This pattern occurs in the diameter class distributions from Benton County. The twelve inch and fourteen inch diameter classes each contain about 18% of the total trees and additional peaks occur at eighteen inches and twenty-four inches. The surveyors obviously estimated the diameters to the nearest six inches in many cases. The average diameter is 13.4 inches, which is the same as that found for the presettlement forest of the River Hills region of Missouri (Wuenschel and Valiunas 1967). The average diameter in the barrens is seven inches, at least partly because the dominant species, post and blackjack oaks, are among the slowest growing species found in the area (Fowells 1965).

GEOLOGY AND TOPOGRAPHY

Since slope in the Truman Reservoir is basically a function of bedrock type, it is also possible to plot vegetation in a general way on the basis of geology. Figure 2.3 shows the location of Ordovician, Mississippian and Pennsylvanian age deposits in Benton County, Missouri, as well as the distribution of the dominant post oak and white oak, and prairie (corresponding to shale and sandstone) for the same area. It is obvious from the distribution of dominant vegetation types that even at the time of the federal land surveys, prior to which there had probably been considerable climatic and anthropogenic modification of the vegetation, it was overwhelmingly under the control of bedrock and surficial deposits.

When the composition of the post oak and white oak dominated areas are compared (Tables 2.2 and 2.3) several differences emerge. Very nearly the same proportions of points occur in bottomland, slope, and upland in both cases, but the distribution of forest, prairie and barrens on these points is greatly different. In the white oak area, 95.6% of the area is forested, compared to only 61.2% in the post oak area. Prairie and barrens, which scarcely occur in the white oak area, account for 27.9% and 10.5% of the post oak area vegetation respectively. The greatest difference is on the slopes where 73.7% of the white oak area is forested compared to 46.2% of the post oak area. Species composition also differs in the white oak dominated area, with white oak in all topographic zones at least three times the value in similar zones in the post oak dominated areas. Post oak and black oak values are much lower than in the flatter lying post oak dominated area, and only in the upland post oak area was the most xeric species (blackjack oak) abundant, and only in post oak area bottomlands was bur oak, a pioneer species, abundant (Weaver 1960).

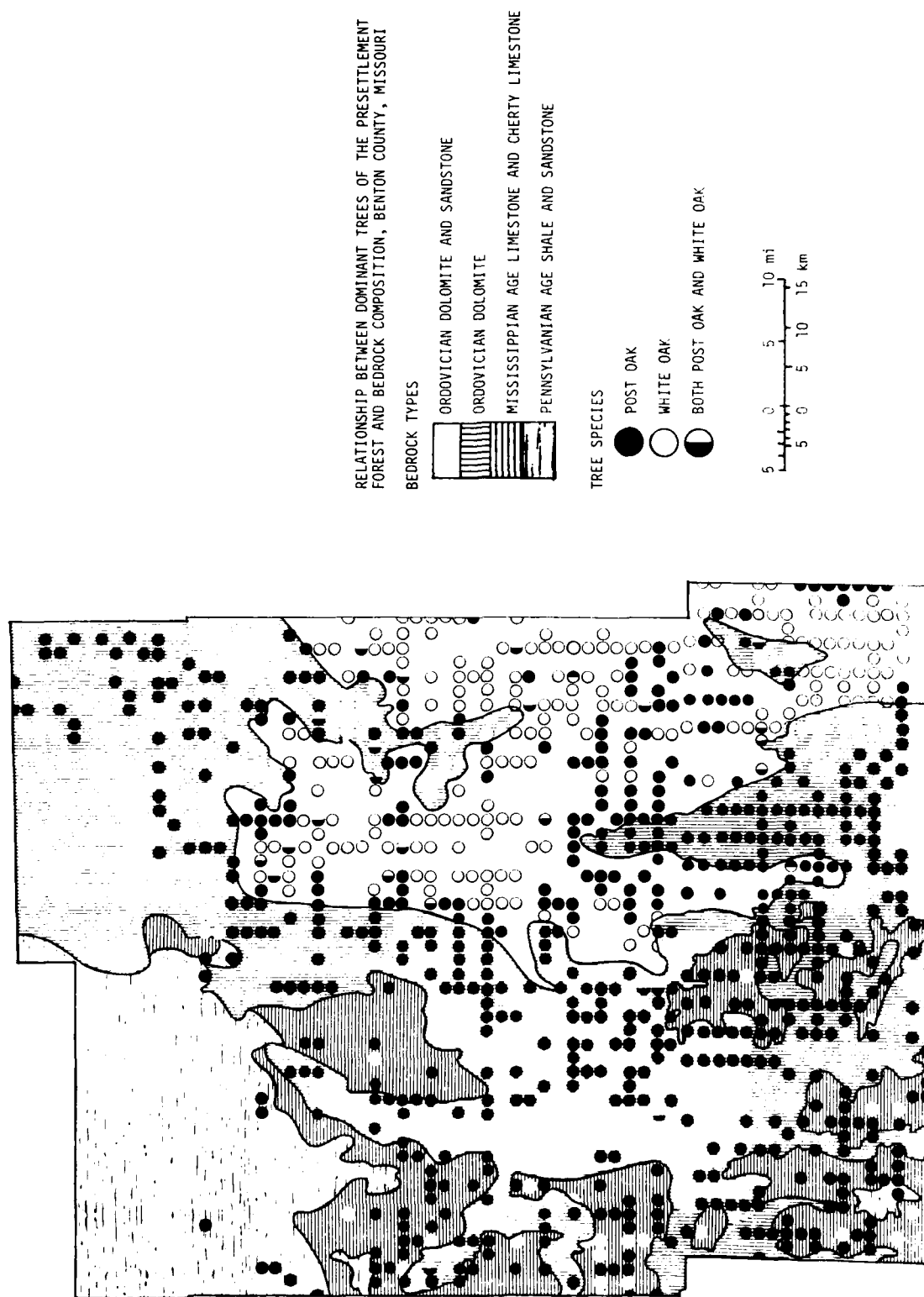


Figure 2.3. Relationship between dominant trees of the presettlement forest and bedrock, Benton County, Missouri.

TABLE 2.2

Distribution of Presettlement Vegetation Types by Landform,
and Substrate, Benton County, Missouri

Vegetation Type	Bottomland	Slope	Upland	Total
<u>WHITE OAK AREA</u> (Roubidoux sandstone & dolomite)				
Forest	12.6	73.7	9.1	95.6
Prairie	0.7	1.2	---	1.9
Barrens	0.2	2.3	---	2.6
Total	13.5	77.2	9.1	100.0
<u>POST OAK AREA</u> (Jefferson City limestone-Burlington dolomite)				
Forest	10.2	46.2	4.6	61.2
Prairie	4.1	20.1	3.8	27.9
Barrens	1.0	8.9	0.6	10.5
Total	15.4	75.4	9.0	99.7

There is also a distinct change in slope forest composition at various aspects and elevations, although the most abundant species in all slope situations is post oak, followed by either black or white oak. The slope forests range from relatively mesic (north and east facing lower slopes) to xeric (south and west facing upper slopes). Black oak and white oak reach greater abundance on nearly all slopes than in flat bottomlands or uplands. Post oak and blackjack oak, characteristic of more droughty soils, are most abundant on uplands and on upper south and west facing slopes. Bur oak and elm occur much more frequently in bottomlands than on slopes.

Post oak reaches its greatest abundance on the gentler 2-5% slopes and on the upper, exposed slopes, while white oak most nearly dominates the steeper slope categories. If tree species distribution is compared for the flatter area dominated by post oak and the steeper white oak dominated area, it is obvious that some factor other than slope is influencing forest composition. Post oak is more abundant in the first area regardless of slope and white oak in the second. Importance values (percent relative frequency plus percent relative dominance, i.e., basal area) for the post oak dominated areas are shown in Table 2.4.

MODERN VEGETATION

Modern vegetation was sampled for, first, comparison with pre-settlement data and, second, to provide information about potential non-arboreal plant resources. The method used was a series of circular plots 50 feet in diameter (0.2 acres in area). The species and diameter at 1.3 m above the ground of each tree over four inches in diameter were recorded. The shrubs and saplings were recorded in four 1 meter square quadrats north of the center point of each plot, while herbs were listed for a 1 m² quadrat. Herbaceous data are poorest since the Ozarks show

TABLE 2.3

Relative Tree Density Presettlement Forest, Benton County, Missouri
Comparison of area dominated by post oak and white oak

Species	Bottomland		Slope		Upland		Barrens	
	Post Oak	White Oak	Post Oak	White Oak	Post Oak	White Oak	Post Oak	White Oak
Post oak (<i>Quercus stellata</i>)	11.7	---	41.1	17.0	50.9	31.6	54.7	44.4
Black oak (<i>Q. velutina</i>)	18.0	9.6	26.2	19.9	18.9	15.8	20.0	11.1
White oak (<i>Q. alba</i>)	8.1	26.9	12.6	45.2	---	34.2	4.0	44.4
Blackjack oak (<i>Q. marilandica</i>)	1.8	---	6.2	5.1	18.9	2.6	2.7	---
Bur oak (<i>Q. macrocarpa</i>)	18.9	7.7	1.1	---	1.9	2.6	---	---
Red oak (<i>Q. rubra</i>)	---	1.9	---	2.9	---	7.9	---	---
Chinkapin oak (<i>Q. prinoides</i>)	1.8	---	2.3	0.6	---	---	1.3	---
Pin oak (<i>Q. palustris</i>)	7.2	---	3.0	0.6	1.9	2.6	2.7	---
Water oak (cf. <i>Q. bicolor</i>)	1.4	3.8	0.2	0.3	---	---	2.7	---
S oak (cf. <i>Q. imbricaria</i>)	---	---	---	---	---	2.6	---	---
Oak (<i>Quercus</i> spp.)	---	---	---	---	1.9	---	---	---
Black hickory (<i>Carya texana</i>)	0.9	---	0.2	0.3	---	---	5.3	---
White hickory (<i>C. tomentosa</i>)	---	---	0.2	---	---	---	---	---
Shagbark hickory (<i>C. ovata</i>)	---	---	---	---	---	---	1.3	---
Hickory (<i>Carya</i> spp.)	5.4	7.7	4.7	3.2	3.8	---	4.0	---
Pecan (<i>C. illinoensis</i>)	0.9	---	---	---	---	---	---	---
Black walnut (<i>Juglans nigra</i>)	4.5	5.7	0.8	1.2	---	---	1.3	---
Butternut (<i>J. cinerea</i>)	---	---	---	0.3	---	---	---	---
Elm (<i>Ulmus</i> spp.)	8.1	13.5	0.8	1.0	---	---	---	---
White elm (<i>U. americana</i>)	3.6	---	---	---	---	---	---	---
White ash (<i>Fraxinus americana</i>)	0.9	1.9	0.2	---	---	---	---	---
Ash (<i>Fraxinus</i> spp.)	1.8	---	0.4	0.3	---	---	---	---
Hackberry (<i>Celtis occidentalis</i>)	0.9	3.8	---	---	---	---	---	---
Honey locust (<i>Gleditsia triacanthos</i>)	---	1.9	---	---	---	---	---	---
Sycamore (<i>Platanus occidentalis</i>)	---	13.5	---	---	1.6	---	---	---
Persimmon (<i>Diospyros virginiana</i>)	---	---	---	0.3	---	---	---	---

TABLE 2.3 (concluded).

Species	Bottomland		Slope		Upland		Barrens	
	Post Oak	White Oak	Post Oak	White Oak	Post Oak	White Oak	Post Oak	White Oak
Red cedar (<i>Juniperus virginiana</i>)	0.9	----	----	0.3	----	----	----	----
Sugar maple (<i>Acer saccharum</i>)	0.9	----	----	----	0.6	----	----	----
Maple (<i>Acer</i> spp.)	0.9	----	----	----	----	----	----	----
Cherry (<i>Prunus</i> spp.)	0.9	----	----	----	----	----	----	----
Basswood (<i>Tilia americana</i>)	----	----	0.2	----	----	----	----	----
Total	99.5	97.9	100.2	98.5	100.4	99.9	100.0	99.9

TABLE 2.4

Importance Values for Post Oak Dominated Area Presettlement Vegetation, Benton County, Missouri

Species	Bottom-land		Bottom-land		Slope		Slope		Slope		Upland		Upland	
	Forest	Prairie	Barrens	land	Forest	Prairie	Barrens	Prairie	Barrens	Forest	Prairie	Barrens	Forest	Barrens
Black oak	35.2	14.1	10.7		53.3	36.2	37.3			43.4	102.4	26.4		
Blackjack oak	4.2	0.0	8.6		10.3	13.1	14.8			26.5	34.5	37.5		
Black walnut	3.2	5.4	9.2		1.8	2.5	0.8			0.0	0.0	0.0		
Bur oak	41.9	63.1	7.9		2.9	5.6	1.3			2.9	0.0	0.0		
Chinkapin oak	3.3	0.0	0.0		4.8	0.0	4.6			0.0	0.0	0.0		
Elm	15.2	13.3	22.1		1.4	1.6	0.0			2.8	0.0	0.0		
Hackberry	3.6	0.0	11.7		0.2	0.0	0.0			0.0	0.0	0.0		
Hickory	14.6	7.9	0.0		6.9	3.7	5.4			6.4	0.0	0.0		
Pin oak	11.2	5.1	0.0		5.2	12.1	3.6			4.2	27.1	10.0		
Post oak	21.0	19.0	54.9		82.1	100.5	109.7			108.2	35.9	111.6		
Red oak	2.0	0.0	0.0		1.0	0.0	0.0			0.0	0.0	0.0		
White elm	6.0	0.0	30.1		0.0	0.0	0.0			0.0	0.0	0.0		
White oak	15.9	0.0	0.0		26.3	16.1	7.5			0.0	0.0	0.0		
Water oak	3.2	0.0	8.0		0.5	5.8	2.0			0.0	0.0	0.0		
Sycamore	0.0	5.4	19.6		0.2	0.0	2.9			1.5	0.0	0.0		
Other	18.3	66.8	17.0		3.0	2.7	10.3			1.4	0.0	14.6		
Total	198.8	200.1	199.8		199.9	199.9	200.2			197.3	199.9	200.1		
N	281	33	20		130	83	179			164	10	16		

strong seasonal (aspect) dominance by certain short lived types which are not apparent earlier or later in the season, and our samples record a single point during the season. Identifications and taxonomy are based on Steyermark (1963).

The number and size of quadrats adequate to sample vegetation varies with the diversity of the plant community (Oosting 1956:44-45). However, the quadrat method requires fewer points than either the point centered quarter or random pairs method. The use of a smaller number of larger plots is desirable when the area is disturbed and the stands small. Numerous studies in the past have used relative density and relative dominance (basal area) to calculate importance values (Cottam and Curtis 1949) and this information is comparable between the two methods.

Stratified sampling included plots in major topographic and vegetation types. Probably all of the sample plots had been disturbed by lumbering at some time in the past, some much more recently than others. In certain plots we found stumps of large oaks or walnuts and these were recorded and used in calculations of tree density and basal area. The types of plots sampled include steep east facing slopes (1-3, 34-36, 51, 52), recent burns (4-8), gently sloping upland forest (9-11, 37-43, 59-65), steep south facing slopes (12-20, 57-58), lower slopes (21, 33, 54), terraces (22-25, 53), slope forests (26-32, 44-45, 50) and bottomland (46-49) (Fig. 2.4.). Each series of plots was begun at a point 100 feet in a previously selected direction from the randomly chosen point where we entered the stand, and additional plots were sampled at 200 foot intervals along a line with the same compass bearing.

RESULTS

Thirty-six tree species were encountered in the sixty-five plots (Table 2.5). Black oak occurred in most plots (63%), followed by post oak (50.7%), white oak (41.5%), chinkapin oak (36.9%), juniper (30.7%), blackjack oak (23.1%), and shagbark hickory (23.1%).

Forest composition varied from stands on uplands with gentle slopes and deep soils dominated by relatively mesic species such as white oak and red oak, through white oak and black oak, black oak and post oak, and finally, on dry, rocky ridgetops, post oak and blackjack oak. Even the driest sites dominated by blackjack oak also contained considerable percentages of white oak suggesting that species distribution was strongly influenced by microenvironment, a factor which would be especially important in the western Ozarks region where subsurface drainage systems are well developed and the soil varies from relatively thick soils derived from loess to thin rocky soils underlain at shallow depth by an impenetrable fragipan layer (Scrivner *et al.* 1966). Also in this area, the Jefferson City-Cotter dolomite and Chouteau and the fossil rich Burlington limestone are interbedded with chert and quartz sandstone (Ward and Thompson 1977) increasing the potential diversity of the forest by changing the nature of the bedrock from which the soils are derived (Read 1952, Kucera and Martin 1957).

The primary tree species in the seedling-sapling stage (Table 2.6) are white oak and slippery elm with some black oak, hackberry, green and white ash, and shagbark hickory on the mesic sites and post oak and blackjack oak on the dry ones. Although these forests have probably been dis-

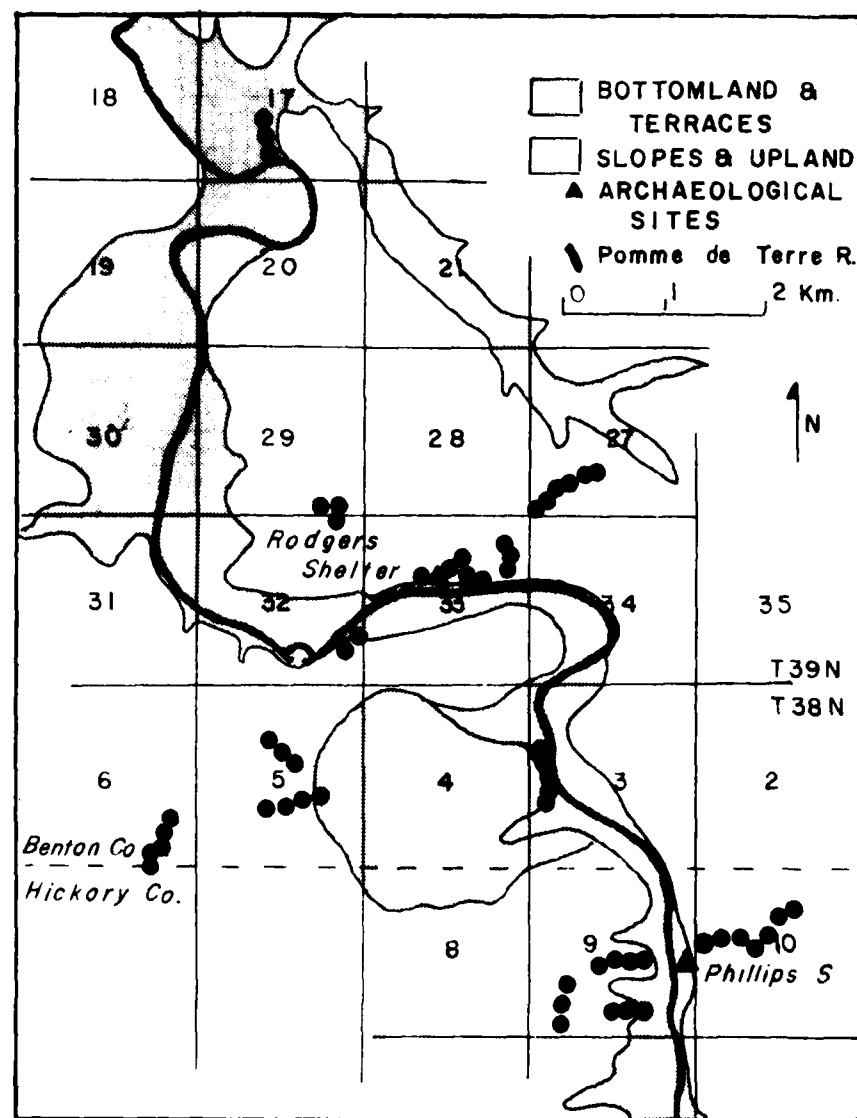


Figure 2.4. Map of Rodgers Shelter area showing the locations of plots 1-57 at which modern vegetation was sampled.



TABLE 2.6

Common and Locally Abundant Understory Plants Encountered in
Modern Vegetation Plots

SHRUBS AND VINES

Campsis radicans (trumpet creeper)
Ceanothus americanus (New Jersey tea)
Cercis canadensis (redbud)
Cornus spp. (dogwood)
Lindera benzoin (spice bush)
Menispermum canadensis (Moonseed)
Parthenocissus quinquefolia (Virginia creeper)
Ptelea trifoliata (hoptree)
Ribes missouriense (gooseberry)
Rhus aromatica (fragrant sumac)
Rhus glabra (smooth sumac)
Rhus toxicodendron (poison ivy)
Rosa spp. (wild rose)
Smilax spp. (greenbriar)
Symphoricarpos orbiculatus (buckbush)
Viburnum rufidulum (blackhaw)
Vitis spp. (grape)
Zanthoxylum americanum (prickly ash)

SAPLINGS

Acer negundo (boxelder)
Acer saccharum (sugar maple)
Bumelia lanuginosa (gum bumelia)
Carya ovata (shagbark hickory)
Celtis occidentalis (hackberry)
Diospyros virginiana (persimmon)
Fraxinus americana (white ash)
Fraxinus pennsylvanica (green ash)
Juglans nigra (black walnut)
Juniperus virginiana (juniper)
Prunus serotina (wild cherry)
Quercus alba (white oak)
Quercus marilandica (blackjack oak)
Quercus prinoides (chinkapin oak)
Quercus stellata (post oak)
Quercus velutina (black oak)
Ulmus rubra (slippery elm)
Tilia americana (basswood)

HERBS

Ambrosia artemisiifolia (ragweed)
Antennaria neglecta (pussytoes)
Arenaria sp. (sandwort)
Asarum canadense (wild ginger)

TABLE 2.6 (concluded).

<i>Chenopodium</i> spp. (lambsquarter)
<i>Daucus carota</i> (Queen Anne's lace, wild carrot)
<i>Desmodium</i> spp. (tick trefoil)
<i>Galium</i> spp. (cleavers)
<i>Impatiens biflora</i> (touch-me-not)
<i>Lactuca</i> spp. (wild lettuce)
<i>Laportea canadensis</i> (nettle)
<i>Lepidium</i> spp. (peppergrass)
<i>Lespedeza</i> spp. (bush clover)
<i>Oenothera missouriensis</i> (Missouri primrose)
<i>Oxalis</i> spp. (oxalis, sourgrass)
<i>Plantago rugelii</i> (plantain)
<i>Podophyllum peltatum</i> (may apple)
<i>Potentilla</i> spp. (cinquefoil)
<i>Pycnanthemum</i> sp. (mountain mint)
<i>Sanguinaria canadensis</i> (blood root)
<i>Solidago</i> spp. (golden rod)
<i>Teucrium canadense</i> (germander)
<i>Trifolium</i> spp. (clover)
<i>Urtica gracilis</i> (nettle)
<i>Uvularia grandiflora</i> (bellwort)
<i>Veronia</i> sp. (ironweed)
<i>Viola</i> spp. (violets)

turbed in the past, the species present as seedlings and saplings are, in most cases, the same as the canopy. This suggests that the upland forests have reached an edaphic or climatic climax or continue to be maintained in a preclimax condition by disturbance.

The most frequent shrubs include spicebush, rose, poison ivy, dogwood, virginia creeper, and greenbriar; while the groundcover includes bedstraw, tick trefoil, bush clover, and grass on the moist sites with pussytoes, grass and mountain mint on the drier ones.

Relatively gentler slopes with some soil development support a forest even more characteristic of this portion of the Truman Reservoir. These stands were strongly dominated by post oak either in association with black oak or mockernut hickory or blackjack oak, depending on the dryness of the site. The number of seedlings and saplings on the slopes are low, as they are in the uplands. Again, the saplings are dominated by the major species in the area and indicate that slope forests are changing little. Shrubby undergrowth is primarily fragrant sumac, dogwood, virginia creeper, redbud, and buckbrush. The ground cover was primarily types such as pussytoes, golden rod, grass, bush clover and tick trefoil.

Steeper slopes or bluffs having little or no soil overlying the dolomite or limestone bedrock are covered by open "cedar glades" usually dominated by red cedar but also often supporting sugar maple, chinkapin oak, green ash, or walnut in more mesic situations.

Bluff and glade seedlings include juniper, red cedar, black oak,

chinkapin oak, sugar maple, hackberry and green ash. Of these, only hackberry is not common in the overstory of the bluffs, although it is abundant on the terraces below and its presence is probably due to birds eating the seeds and dropping them on the bluff. All of these species, including hackberry, grow well on limestone. The shrubs on the bluff consisted almost entirely of fragrant sumac, buckbrush, and redbud, with an occasional prickly ash or bumelia.

Cedar glades such as the one on Buzzards Cave Bluff east of Rodgers Shelter are rare in the presettlement vegetation of the Truman Reservoir area, occurring at only four localities along the Pomme de Terre. Red cedar (juniper) is presently the most widely distributed tree-size conifer in the eastern United States (Fowells 1965). It is frequently found on thin soil with limestone or dolomite outcrops, usually being outcompeted on better sites by hardwoods. It withstands drought well (Albertson and Weaver 1945), but it is very susceptible to fire damage. Beilman and Brenner (1951), describing the presettlement vegetation of the northeastern Ozarks, say that it was scarcely known at early times but once fire had stopped, the red cedar had demonstrated "that it can, in a short time, become the dominant tree in the entire Ozarks region."

Lower slopes have a higher species diversity with more mesic species including pawpaw, boxelder, honey locust, sugar maple, basswood, hackberry, walnut, and shellbark, bitternut, and mockernut hickory. The undergrowth was predominately virginia creeper, buckbrush, grape, spicebush, gooseberry and pawpaw. The groundcover included touch-me-not, violets, wild ginger, and nettles, bloodroot and may apple.

The riverbanks of the Pomme de Terre are dominated by sycamore and silver maple, while terraces have silver maple, boxelder, basswood, and American elm, and slightly higher, increasing amounts of hackberry, slippery elm, and white ash. The undergrowth of the bottomlands is primarily virginia creeper, dogwood, buckbrush, trumpet creeper, grape and greenbriar.

Tree species distribution in the bottomland corresponds to a moisture and flooding gradient (Bell 1974). Burgess *et al.* (1973) found American elm, bur oak, boxelder and green ash occurring in the older, more mature floodplain in North Dakota with cottonwood and willow in lower, wetter, and younger sites. Weaver *et al.* (1925) and Weaver (1960), in studies of the central Missouri valley, found in Kansas several bands of forest communities extending along the rivers: red oak-linden (basswood), black oak-shellbark hickory, and bur oak-bitternut hickory. The bur oak community is frequently bordered by a shrub community which separates it from the prairie. This shrub community includes many species already listed for the Pomme de Terre as well as others such as elderberry, gooseberries, bittersweet, and hazelnut.

COMPARISON OF PRESETTLEMENT AND MODERN FORESTS

The species present in the western Missouri Ozarks were not noticeably different in presettlement times than they are at present and so little time has elapsed (150 years) that plant communities could not have evolved to any significant degree. Nonetheless, there are several obvious differences between the presettlement and modern vegetation of this area. The most notable changes have occurred in density, and in the absence

from the modern forest of anything that might be called "barrens," a term that generally is used for less than two trees/acre.

The determination of the factors which were of prime importance in shaping the presettlement forests of the western Missouri Ozarks, whether they be edaphic, climatic, or fire, are difficult to judge since we are working in a diverse area with widely varying topography and soils. The questions remain: What is the climax vegetation of this area? How, if at all, does it differ on the basis of bedrock and soils? What effect did the Hypsithermal and the "Neoglacial" or "Little Ice Age" have on the prairie forest border? What was the effect of fire on forest succession and development?

The frequency of mesic tree species (e.g., white oak) decreases towards the western border of the eastern deciduous forest, being more and more frequently replaced by drought tolerant oaks and hickories until post and blackjack oaks dominate in most upland situations. Woodlands are no longer continuous, becoming more and more strictly confined to stream valleys with prairie on the uplands. Throughout central and western Missouri, occasional small remnants of more mesophytic forests are found in exceptionally favorable situations, suggesting that such forests may once have been more widespread. Kucera and McDermott (1955) studied such fragmentary stands of sugar maple and basswood in central Missouri and Wells and Morley (1964) described a rich mesic forest relatively far west in Kansas.

In western Missouri and the adjacent portions of Kansas, Oklahoma and Arkansas, climatic conditions are marginal for tree growth so that soils and topography become of critical importance in determining the presence or absence of forest (Brunner 1931). Throughout this region, post oak and blackjack oak dominate on droughty soils. The shallower and drier the soils, the more dominant the blackjack oak (Küchler 1974, Brunner 1931, Rice and Penfound 1959). Heavier soils in this region are covered by prairie.

In the eastern part of the transition zone, forests often also include the more mesic black oak. However, in the Chautauqua Hills of eastern Kansas, black oak and blackjack oak never occur together, indicating the additional moisture stress on trees in that relatively dry area (Lathrop 1958). In more mesic sites in Missouri, white oak is often the dominant species in associations including not only blackjack oak and post oak but black oak, red oak, shagbark, bitternut and mockernut hickories (Küchler 1964, Braun 1950:166). Steep ravines and protected lower slopes have mixed communities in which sugar maple may dominate in association with red oak and basswood (Braun 1950:186, Kucera and Martin 1957). Bur oak is also common, generally on lower ground or along streams (Kucera 1961).

White oak generally grows well on all but the driest shallow soils, while being limited by nutrient availability only on very sandy soils, and on such droughty or sandy soils it is generally replaced by the slower growing and less shade tolerant post oak and blackjack oaks it outcompetes elsewhere. In the Arkansas Ozarks, Read (1952) found white oak in combination with either black or red oak dominant on north facing slopes comprised of cherty limestone or sandstone with red cedar predominating on limestone. Just to the north in the White River basin, Kucera and Martin (1957) found post oak in forests peripheral to cedar

glades with black oak and white oak increasing in size and prevalence as the degree of exposure lessened and soil depth increased. The cedar glades occurred on shallow soils overlying resistant limestone, with forested areas immediately above the glades on soils derived from cherty limestone. Turner (1935) also found post oak and blackjack oak important associates of red cedar on limestone soils and outcroppings, especially on the south facing slopes of ridges whose north facing slopes is occupied by post oak-blackjack oak-winged elm (*Ulmus alata*)-black hickory, black hickory-white hickory, or white oak-red oak-sugar maple.

Since the presettlement land surveys, there has been a tremendous increase in the amount of red cedar, not only in the Truman Reservoir, but throughout the Ozarks (Beilman and Brenner 1951; Howell and Kucera 1956). The increase is probably due to the cessation of periodic burning as the land was settled, enabling the growth of fire susceptible red cedar as well as other fire sensitive species such as sugar maple (Wuenscher and Valiunas 1965). In modern forests, the distribution of red cedar has certainly been much increased by cutting and overgrazing as well since cattle selectively chose not to eat the prickly juniper seedlings. However, from the four sites in the Pomme de Terre River Valley at which red cedar was recorded at the time of the land surveys, it has since spread to steep, south facing exposures with little or no soil, and it is these sites where it can grow competitively with other species.

Tree density has also increased significantly since presettlement times, although it is difficult to judge the degree because of bias on the part of the surveyors. If presettlement forests are compared with modern stands on the basis of average diameter and density, there is a greater disparity between the two (Fig. 2.5). If, however, modern forest density is calculated on the basis of only trees ten inches or greater in diameter, making the data more comparable to the similarly size biased surveys, the diameters are similar, although the density per acre remains quite low, especially for barrens and bottomlands. The low bottomland tree density might be further explained by surveyor bias against very large diameters as well as small, since bottomland forests tend toward very large trees. However, this still leaves the "barrens" with a low tree density which might be best interpreted as the effect of fire killing young trees and opening up the forest canopy.

Although the potential climax vegetation of the area seems to vary somewhat by bedrock and soil types, it appears that the topography of the Truman Reservoir area is sufficiently steep and the soils sufficiently coarse for forest to have never been completely replaced by prairie at any point during the Holocene, rather being reduced to an open savannah or "barrens" unlike the present mosaic of well developed forest and prairie (Dyksterhuis 1957, Küchler 1974). Marbut (1911) found, "The greater part of the Ozark Dome was up to the middle of the 19th century, a region of open woods, large areas being almost treeless. Except on the roughest land, the thoroughly dissected portions of the Clarksville soils, the rough stony land, the Decatur soils, and the more hilly portions of the Boston Mountain Plateau, the timber growth was not dense enough to hinder, in any way, the growth of the grass. The whole region in its vegetation was more closely allied to the western prairies..."

However, fire alone cannot eradicate most oak and hickory species, only killing them back to ground level from which they sprout readily and

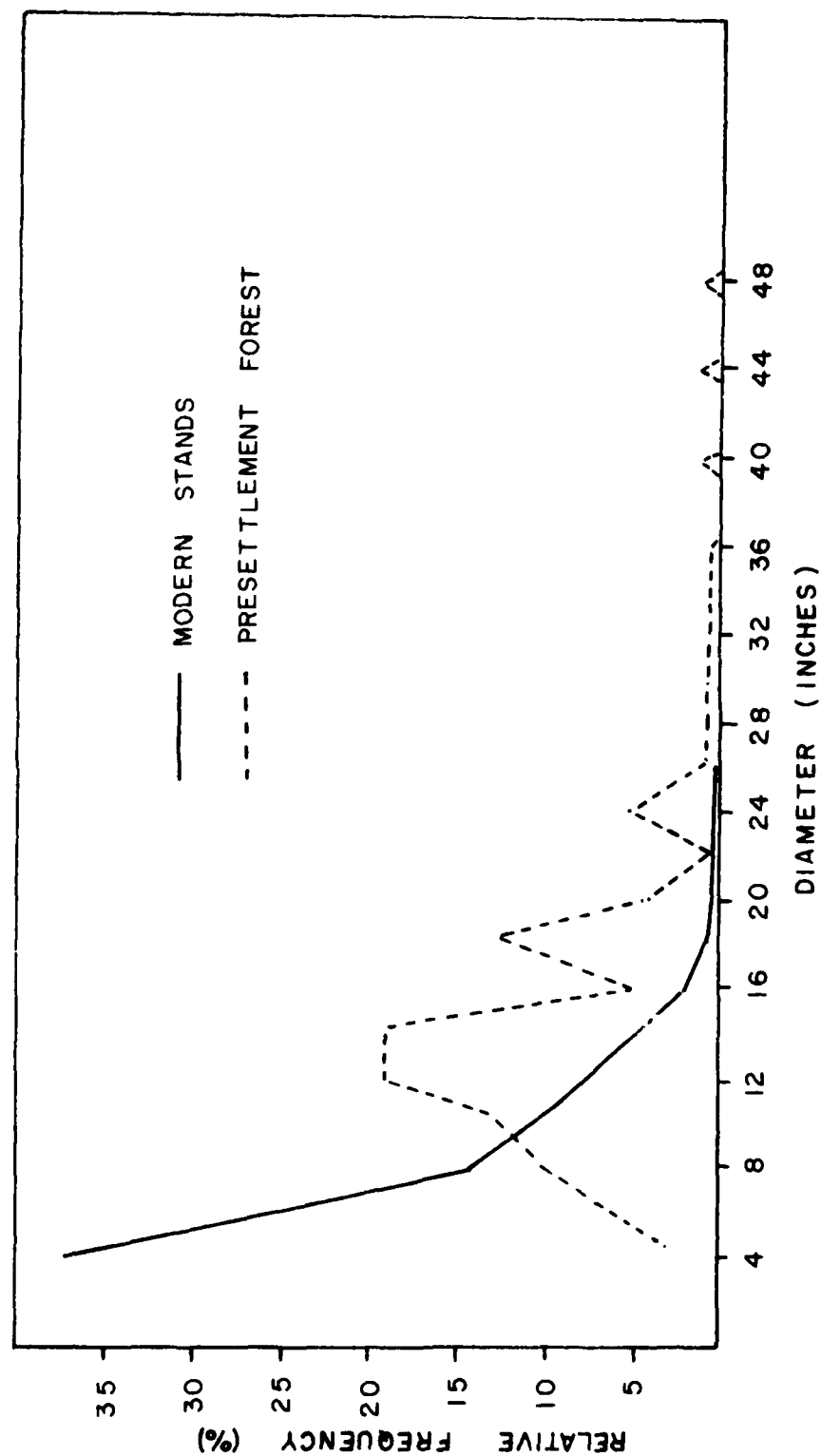


Figure 2.5. Comparison of diameter class distributions for modern and presettlement forests, Benton County, Missouri.

vigorously (Curtis 1959, Fowells 1965). For this reason, the "barrens" vegetation of the Ozarks could probably not have evolved entirely as a result of fire and climate must also have been an important factor.

The G.L.O. surveyors in the Truman Reservoir frequently described a situation in which open barrens occurred on the south sides of ridges and open oak woods on the north or, "land this mile open barrens, black oak, white oak or post oak on north sides of hills, valleys and south slopes prairie or very open barrens" or "rolling open black oak and post oak with prairie hollows and barren hillsides" (James 1844). Such topographic differences in the vegetation also argue a climatic origin since fire alone could not eradicate forest on the south facing slopes or in valleys, without also affecting north facing slopes and uplands. It appears that these "barrens" must have originated at an earlier, drier period; and since certain areas in the Truman Reservoir, as throughout the Ozarks, were being invaded by forests at the time of white settlement, a moister climatic regime, coupled with a decreased incidence of burning was the probable cause of their demise.

Of the two dominant tree species, post oak distribution more closely follows that of temperature while white oak distribution seems to reflect precipitation (Fowells 1965). Since the Hypsithermal was probably characterized by primarily drier conditions and possibly by warmer summer temperatures (Wright 1976a, King and Allen 1977), drying would limit the distribution of the relatively mesic white oak more severely than that of the drought tolerant post oak. Once relatively moist climatic conditions returned, the spread of post oak would be hastened by its wider initial occurrence, while the re-expansion of a mesic species such as white oak would be hampered in the flat-lying western portions of the Truman Reservoir by the distance between suitable protected habitats and by the vulnerability of young seedlings to periodic fires which would burn more widely in the gentler topography.

PRAIRIE: UPLAND AND BOTTOMLAND

Unfortunately, the G.L.O. surveyors did not record the composition of the tall grass prairies through which they passed, and the vast majority of these areas have long been destroyed through cultivation or grazing. Competitive non-native species such as Kentucky bluegrass have also assumed a dominance in many stands at the expense of the native species.

Fortunately, in the prairie stands which have been preserved, it is possible to observe a distribution of species in which prairie communities are clearly related to water content of the soils and little to local soil types (Weaver and Fitzpatrick 1934, Weaver 1954).

The wettest, most poorly drained soils are occupied by tall sedges, rushes, and marsh grasses such as slough grass, or reed canary grass, with the slough grass becoming dominant on slightly drier sites. In the past, slough grass covered hundreds of square miles of bottomlands along the Missouri and Mississippi rivers.

The drier portions of the slough grass community are occupied by switchgrass and nodding wild rye although they never reach the extensive areas once occupied by the slough grass community. The broad, well drained valleys of larger streams and slopes and lower hillsides are dominated by big bluestem (*Andropogon gerardi*) with Indian grass

(*Sorghastrum nutans*) becoming more abundant in areas periodically burned or flooded. The upland sites are dominated by little bluestem (*Andropogon scoparius*), side oats grama (*Bouteloua curtipendula*) or junegrass (*Koeleria cristata*) (Weaver 1954).

Herbaceous plants are also important in the prairie. Tables 2.7 and 2.8 list the most important forbs in the lowland and upland prairie (Weaver 1954) and they indicate the species which produce potential human food resources.

The origin of the bottomland prairie recorded by the G.L.O. surveyors are of great interest, especially since one such prairie occurs adjacent to Rodgers Shelter. The origin of these prairies may, to some extent, be edaphic, since as has already been discussed, prairie species grow better on fine textured, poorly aerated soils, than do woody species and the alluvial soils in at least some of the bottomlands such as the Breshears Valley tend to be finely textured and poorly drained clays and silts interbedded with gravel (Haynes 1976, 1977).

Curtis (1959:305), on the other hand, felt that wet prairies are probably unstable, in the absence of fire being quickly invaded by flood tolerant trees such as willow, cottonwood and ash. He felt that they were definitely of a temporary nature and could have originated from lowland forests at any time in the past and that it is possible they originated at the time of the expansion of upland prairies (Hypsithermal) because fires in the uplands would have spread into the lowlands as well.

The line descriptions recorded by the G.L.O. surveyors tend to support Curtis' (1959) view that fire was an important factor in the maintenance of these bottomland prairies. Shields (1834), for example described the vegetation of the east side of section 12, T39N R23W (near Fairfield) as follows: "bottom was prairie but now grown up in Hazle [sic] or low bushes." This area was well developed, with many farms, roads and a ferry landing at the time, so that fires were probably suppressed whenever possible.

ABORIGINAL USE OF FIRE

If fire had as much effect on vegetation along the prairie-forest boundary as seems evident from the G.L.O. survey records, the role of the Indian in determining fire frequency and location needs to be examined. The Indians had numerous good reasons for using fire including: exposing game, concentrating animals in the remaining good habitat, clearing land for agriculture, selecting for certain more tolerant plant species such as hazel nuts or blackberries, communications, increasing visibility and mobility, reducing and repelling insects, predators and enemies, and to minimize the effects of uncontrolled natural or warfare fires (Vogl 1974). With all of these uses for fire, it seems possible that the Indians may have considerably increased the frequency of fire in the Midwest. Fires are a part of the natural grassland ecosystem (Davis 1977) and are facilitated by the dormant periods, dry seasons, and periodic droughts characteristic of the prairie; they only burn widespread areas under sufficiently dry and/or windy conditions, and strong fire-climate relationship probably exists. Once a fire has swept through an area, the area is probably safe until, at least, the end of the following growing

TABLE 2.7

Principal Lowland Forbs of the Eastern Tallgrass Prairie
Listed in Approximate Order of Importance, Based on Weaver (1954)

* <i>Fragaria virginiana</i> Scarlet strawberry	<i>Vernonia fasciculata</i> Western ironweed
<i>Lysimachia ciliata</i> Fringed loosestrife	* <i>Helianthus tuberosus</i> Jerusalem artichoke
<i>Aster praealtus</i> Willow aster	* <i>Asclepias incarnata</i> Swamp milkweed
<i>Anemone canadensis</i> Canada anemone	<i>Hypoxis hirsuta</i> Star grass
* <i>Solidago altissima</i> Tall goldenrod	<i>Heliopsis helianthoides</i> Oxeye
* <i>Silphium laciniatum</i> Compassplant	<i>Thalictrum dasycarpum</i> Tall meadow rue
<i>Phlox pilosa</i> Prairie phlox	<i>Polygonum coccineum</i> Water smartweed
<i>Silphium integrifolium</i> Entire-leaved rosin weed	<i>Rudbeckia hirta</i> Black-eyed Susan
<i>Helianthus grosseserratus</i> Saw-tooth sunflower	<i>Ratibida pinnata</i> Coneflower
<i>Liatris pycnostachya</i> Prairie button snakeroot	<i>Senecio aureus</i> Golden ragwort
<i>Equisetum laevigatum</i> Scouring rush	<i>Lycopus americanus</i> Water hoarhound
<i>Zizia aurea</i> Golden meadow parsnip	<i>Silphium perfoliatum</i> Cup plant
<i>Teucrium canadense</i> American germander	<i>Vernonia baldwini</i> Baldwin's ironweed
<i>Apocynum sibiricum</i> Indian hemp	<i>Desmodium illionense</i> Illinois tick trefoil
<i>Viola papilionacea</i> Meadow violet	<i>Antennaria plantaginifolia</i> Platain-leaf everlasting
<i>Pycnanthemum virginianum</i> <i>P. tenuifolium</i>	* <i>Physalis virginiana</i> Virginia groundcherry
Mountain mint	<i>Astragalus canadensis</i> Canadian milk vetch
<i>Cicuta maculata</i> Water hemlock	* <i>Amphicarpa bracteata</i> Hog peanut
<i>Veronicastrum virginicum</i> Culver's root	<i>Gaura</i> spp. Gaura
<i>Asclepias verticillata</i> Whorled milkweed	* <i>Oxalis violaceae</i> Purple sheep sorrel
<i>Asclepias sullivantii</i> Sullivant's milkweed	* <i>Artemisia ludoviciana</i> Sage
<i>Equisetum arvense</i> Scouring rush	<i>Lathyrus palustris</i> Marsh vetchling
<i>Lythrum alatum</i> Loosestrife	<i>Physalis heterophylla</i> Prairie groundcherry
<i>Erigeron annuus</i> Fleabane	

* Food plant (King 1976)

TABLE 2.7 (concluded)

<i>Erigeron philadelphicus</i>	* <i>Oxalis stricta</i>
Fleabane	Yellow sheep sorrel
<i>Lobelia spicata</i>	<i>Rhus radicans</i>
Pale-spiked lobelia	Poison ivy
<i>Allium canadense</i>	* <i>Helianthus Maximiliana</i>
Wild onion	Maximilian's sunflower
<i>Helenium autumnale</i>	<i>Cacalia tuberosa</i>
False sunflower	Indian plantain

TABLE 2.8

Principal Upland Forbs of Eastern Tallgrass Prairie
Listed in Approximate Order of Importance, Based on Weaver (1954)

* <i>Amorpha canescens</i>	<i>Kuhnia eupatorioides</i>
Lead plant	False boneset
<i>Helianthus laetiflorus</i>	<i>Psoralea tenuiflora</i>
Stiff sunflower	Psoralea
<i>Aster ericoides</i>	<i>Sisyrinchium campestre</i>
Many-flowered aster	Blue-eyed grass
<i>Antennaria neglecta</i>	* <i>Ceanothus ovatus</i>
Prairie cat's-foot	Redroot
<i>Erigeron strigosus</i>	<i>Desmodium canadense</i>
Daisy fleabane	<i>D. illinoense</i>
* <i>Solidago missouriensis</i>	Tick trefoil
Smooth or Missouri goldenrod	<i>Aster laevis</i>
<i>Psoralea argophylla</i>	Smooth aster
Silver-leaf psoralea	<i>Artemisia ludoviciana</i>
* <i>Petalostemum candidum</i>	Sage or mugwort
<i>P. purpureum</i>	<i>Lespedeza capitata</i>
White and purple prairie clover	Bush clover
<i>Echinacea pallida</i>	<i>Schrankia uncinata</i>
Pale purple coneflower	Sensitive briar
<i>Euphorbia corollata</i>	<i>Solidago speciosa</i>
Flowering spurge	Showy goldenrod
* <i>Solidago rigida</i>	<i>Aster azureus</i>
Stiff goldenrod	Sky-blue aster
* <i>Astragalus caryocarpus</i>	<i>Linum sulcatum</i>
Ground plum	Yellow flax
<i>Matris aspera</i>	<i>Achillea millefolium</i>
Large button snakeroot	Milfoil or yarrow
<i>Rosa suffulta</i>	<i>Senecio plattensis</i>
Prairie rose	Prairie ragwort
<i>Coneopsis palmata</i>	<i>Baptisia leucantha</i>
Tickseed	Large white wild indigo

* Food plant (King 1976)

TABLE 2.8 (concluded)

<i>Baptisia leucophaea</i>	* <i>Plantago purshii</i>
Large-bracted wild indigo	Pursh's plantain
<i>Salvia azurea</i>	<i>Eryngium yuccifolium</i>
Pitcher's sage	Rattlesnake master
<i>Ratibida columnifera</i>	<i>Polygala sanguinea</i>
Prairie coneflower	Field milkwort
<i>Pedicularis canadensis</i>	<i>Pedicularis lanceolata</i>
Lousewort	Lousewort
<i>Salix humilis</i>	<i>Callirhoe alcaeoides</i>
Upland willow	Poppy mallow
<i>Anemone cylindrica</i>	<i>Potentilla arguta</i>
Long-fruited anemone	Cinquefoil
* <i>Comandra richardsoniana</i>	* <i>Physalis lanceolata</i>
Bastard toadflax	Prairie ground cherry
<i>Astris squarrosa</i>	<i>Lithospermum incisum</i>
Scaly blazing star	Narrow-leaved puccoon
<i>Ruellia humilis</i>	<i>Onosmodium occidentale</i>
Hairy ruellia	Western false gromwell
<i>Viola pedatifida</i>	* <i>Psoralea esculenta</i>
Prairie violet	Prairie turnip
* <i>Solidago graminifolia</i>	
Fragrant goldenrod	

season when more combustible debris has accumulated; thus the maximum frequency of fire in an area would be once a year. Numerous studies have documented that lightning is a major natural cause of fire in most grasslands throughout the world, and dry periods are often interrupted by lightning storms. Loucks (1970) feels that natural burning along the prairie fringe may have been annual; the conditions favorable for the spread of natural caused prairie fires probably did occur that often. The aboriginal use of fire for the numerous reasons listed above may only have been significantly higher than the normal rate in the forest interior where natural fires would seldom have spread extensively because of the broken topography and natural fire breaks. If this is the case, the frequency of fires in the prairie-forest ecotone of the western Missouri Ozarks may not have changed significantly during the latter Holocene, though the causal agent may have shifted from lightning storms to man, and periodic fires may have continued to maintain the vegetation established under the drier climatic regime of the mid-Holocene, rather than further modifying it.

RESOURCE SCHEDULING, PLANT DIVERSITY, AND PRIMARY PLANT RESOURCES

The primary function of economic activities of hunter-gatherers is to satisfy the food needs and needs for essential non-food materials of a population. Important goals guiding economic behavior while fulfilling that function appear to be minimization of effort and the maintenance of a certain level of security (Jochim 1976:7, 16). Stability, and thus security, in an ecosystem increases with the number of links in the

food web, and for a hunting-gathering society, that means having a large number of diverse food resources so that there is less likelihood that all would be depleted at the same time. Thus, the relationship with the natural environment is perhaps the most important factor conditioning the behavior of hunter-gatherers and the nature of the resources and the necessary subsistence activity probably the primary factors conditioning site placement and demographic arrangements (Jochim 1976:9, 12).

Hunting offers a low probable return at high risk while gathering offers high return at low risk, and because of the necessity of maintaining a certain minimum level of income, one would predict emphasis on the more reliable resources (Lee 1968:40). However, factors other than security or ease of collection such as prestige, sex role differentiation, variety, or taste are also important in determining subsistence activities. Once the achievement of a minimum level of security is assured through gathering or cultivation activities by a certain segment of the community (generally the women and children), the rest of the community (men) are free to fulfill their different sex roles through seeking high prestige, tasty (i.e., fat), high risk resources (animals) with which to add variety to their diet (Jochim 1976:16).

Among many midwestern Indian tribes, there was a seasonal emphasis on certain primary food resources while other, secondary plant and animal resources were utilized to the extent they were desired and accessible during the exploitation of the prime resource. For example, the Kansas Kickapoo as late as 1858 lived together during the summer in a permanent camp where they raised crops and hunting was confined to small bands near the village, summer migrations were made to areas more suitable for hunting, fishing or digging lotus (*Nelumbo lutea*) tubers (Wilson 1953) and there would be a bison hunt of several weeks duration. In the fall, after the crops were harvested, the entire group moved to the winter hunting area, breaking into small groups. Early in the spring, they returned to the summer camps to live on corn they had stored the previous fall.

Among the historic Osage, there were three main hunts: a spring hunt for bear and beaver in March, a summer hunt for bison (perhaps deer during earlier times) in May-July, and a fall hunt for bison or deer from September through December. Relatively permanent villages were utilized during the winter months from December to February or March, while the gardens were being planted in April, and while the crops were harvested in August. Activities dealing with the preparation, preservation, and storage of food were integrated with food acquisition, with emphasis being placed first on game, second on agricultural produce and last on gathered plant foods. Hunting was solely the work of the men and not only the main subsistence activity but also a means of gaining status in the community. Women were entirely responsible for cultivated crops (Chapman 1959).

Similar patterns occurred among many of the other tribes adjacent to the Plains such as the Sauk (Skinner 1925), Pawnee (Weltfish 1965), Fox, Miami, Winnebago, Menomini, Ottawa, and Potawatomi (Quimby 1960). Deliette (Pease and Werner 1934:307-320) found that among the 17th century Illinois Indians, occupation of the semi-permanent summer village began in March after the winter hunt, with the summer hunting lasting from late May after the crops were sown until the end of July when the

early harvest began. After harvesting was completed, the summer village was abandoned and everyone dispersed to winter lodges where there was individual hunting with limited nut and root gathering. In the late winter, there was a bear hunt and another bison hunt.

At the time of white contact, all of the tribes cultivated plants including corn, squash, beans, and sunflower and hunted (Lowie 1954). It is not known precisely how early such cultivated plants may have been important. The first of the introduced cultigens, squash, occurs at Phillips Spring as early as 4280 years ago, and the earliest corn from the midwest is about 2000 years old. For most of the record, therefore, cultivated plants were not present and their place must have been filled by other native cultivated (sunflower, marshelder) or non-cultivated plant or animal foods.

Hunting, particularly communal hunting, is strongly dependent on migration patterns and on behavior patterns which make the animals easier to find or approach. As such, communal hunting schedules are fairly well set and would not be much influenced by variations in plant food availability. In addition, among historic tribes, communal hunts generally took place during the late winter and early summer, both times when plant foods are normally at a minimum. Individual hunting and fishing are year round locality dependent activities and probably not much affected by plant food availability either except that a failure to secure the amounts necessary to fill the minimum caloric needs of a population would probably force the increased exploitation of low prestige, low risk animals such as rabbits or squirrels to make up the difference. However, half the year was spent on agriculture by the historic Indians (Brown 1965) and it is this portion of the year that would be most changed by the absence of cultivated plants. It is during the spring and fall that at least some of the members of a tribe would be engaged in either cultivating plants and harvesting them, or, if cultivated plants did not exist, then in gathering wild food plants. It is during these seasons that camps might be expected to be located for maximum efficiency in exploiting the chosen plant resources.

There are two ways of looking at wild plant foods. One is to focus on certain "primary" plant resources that almost certainly were the most important in aboriginal diets because of their high food value, their storability, or their ease of collection. The other method is to look at the distribution of all potential plant foods under the assumption that usage would be more or less proportional to their overall occurrence.

PRIMARY PLANT RESOURCES

The primary plant resources (Table 2.9), the ones still deemed important by Indians of historic times despite the availability of introduced cultigens, and thus possibly more important throughout the history of man in the Midwest are maple, tapped in the spring and the sap boiled down to sugar which was stored; blackberry, dewberry, raspberry, wild plums and wild cherries, and crab apple, the fruits of which could be collected in the fall and dried; ground nut or Pomme de Terre, Jerusalem artichoke, hog peanut, all wild tubers collected in the spring or late fall; American lotus, prized for its rootstocks and seeds and probably introduced by the Indians far outside its natural range; swan potato,

TABLE 2.9
Primary Plant Resources of the Truman Reservoir

Species	Habitat	Western Missouri Ozarks	Eastern Kansas
<i>Acer</i> spp. (maple)	Bottomland forest	4 spp.	3 spp.
<i>Allium</i> spp. (wild onion)		3 spp.	2 spp.
<i>Amelanchier arborea</i> (shadbush)	Oak-hickory forest, bluffs	X	X
* <i>Amphicarpa bracteata</i> (hog peanuts)	Bottomland	X	X
* <i>Apios americana</i> (ground nut, Pomme de Terre)	Thickets, bottomland	X	X
<i>Asclepias</i> spp. (milkweed)	Bottomland, prairie, barrens		
* <i>Asimina triloba</i> (pawpaw)	Bottomland	3 spp.	3 spp.
* <i>Carya</i> spp. (hickory)		X	X
* <i>Corylus americana</i> (hazelnut)	Bottomland, oak-hickory forest		
* <i>Cospyros virginiana</i> (persimmon)	Bottomland, barrens, O-H forest	7 spp.	4 spp.
<i>Fragaria</i> (strawberry)	Glades, bottomland, barrens	X	X
<i>Helianthus annuus</i> (sunflower)	Prairie, O-H forest, barrens	X	X
<i>H. tuberosus</i> (Jerusalem artichoke)	Prairie, disturbed ground	0	X
* <i>Juglans nigra</i> (black walnut)	Bottomland prairie	X	X
* <i>Nutus pyrus icensis</i> (wild crabapple)	Bottomland, oak-hickory forest	X	X
* <i>Nelumbo lutea</i> (American lotus)	Bottomland, oak-hickory forest	X	X
<i>Physalis</i> spp. (ground cherry)	Ponds, oxbow lakes	X	X
* <i>Prunus</i> spp. (wild cherry, plum)	Forest, prairie	6 spp.	6 spp.
<i>Psoralea esculenta</i> (prairie turnip)	Forest	7 spp.	6 spp.
* <i>Quercus</i> spp. (oak)	Prairie	0	X
<i>Ribes</i> spp. (gooseberries, currants)	Forest	7 spp.	7 spp.
<i>Rubus</i> spp. (raspberries, blackberries, dewberries)	Bluffs, barrens, forest border	2 spp.	2 spp.
* <i>Sagittaria latifolia</i> (arrowhead, swan potato)	Forest, prairie, thickets	7 spp.	5 spp.
<i>Sambucus canadensis</i> (elderberry)	Ponds, slow streams	X	X
* <i>Vitis</i> spp. (grape)	Open woods, bottomland	X	X
	Forest	4 spp.	4 spp.

*Listed by Chapman (1959) as being important food plants of the Historic Osage.

widespread aquatic plant the tubers of which were collected in the fall and winter; and nuts (walnuts, hickory nuts, acorns, hazelnuts). All of these plants were prominent in ethnohistories of tribes from the Great Lakes to the Rocky Mountains. Although the caloric values of these plant foods vary considerably, the timing of their availability is such that each type of food is very important in its season (Fig. 2.6). The most obvious thing about these primary plant resources is that they almost all occur in two basic habitats: floodplains (including marshes, forests) and open woods or thickets, a vegetation type indicative of either an edge situation such as the meeting of forest and prairie or of a disturbance situation, such as fire.

SEASONAL AND SPATIAL DISTRIBUTION OF POTENTIAL PLANT RESOURCES

Many other edible and thus potential food plants occur in the western Missouri Ozarks (King 1976) although many could only be used fresh. Greens and fleshy fruits are less palatable (to modern tastes) or are more difficult to collect. These plants would be of critical importance if the primary plant resources should fail or in seasons they were not available.

Figure 2.6 shows the relative food plant diversity of different vegetation zones in the western Missouri Ozarks for various seasons (based on King 1976). In spring and fall, bottomland has nearly twice as many "potential" food plant species as any other vegetation zone, while during the summer, open woodlands, bluffs, and prairie have nearly as high a diversity as the bottomland. However, many of the same plants occur in different zones so that the greatest additional diversity would seem to come from the proximity of a bluff or glade area to a point in the bottomland. Disturbance around the camp would add more food species as weeds. From the 44 potential plant foods occurring in the bottomland forest in the spring, the number may be increased to over 80 by the added proximity of oak-hickory forest, open woodlands, bluffs/glades, marshes, prairies, and disturbance plants.

The proportion of different types of plant foods also varies by topography and stream rank (Fig. 2.7). The greatest percentage of oaks (acorns) occurs in the slope and upland forests and gradually decreases with higher stream rank and greater moisture. Nuts, produced by the relatively mesic walnut and hickory species, increases with stream rank as do sap producing trees (maple, sycamore) and fruits (plum, pawpaw, cherry, etc.). Figure 2.7 is based on arboreal (tree) distributions and thus does not reflect the distributions of "greens" or potherbs which are more or less ubiquitous.

As noted by Yarnell (1964:45), the number of native economic plant species decreases toward the north and consequently, the reliance on animal food increases, from one-quarter of the diet in the southern United States to three-quarters in the north. The reason for a decrease in the total diversity of plants, including the economic types, is response to the colder climate. This same decline in plant diversity occurs toward any climatic extreme; for example, it occurs toward the west when the climate became drier rather than colder.

There are 164 common potential food plants in the western Missouri Ozarks distributed over several types of vegetation. All of the vegeta-

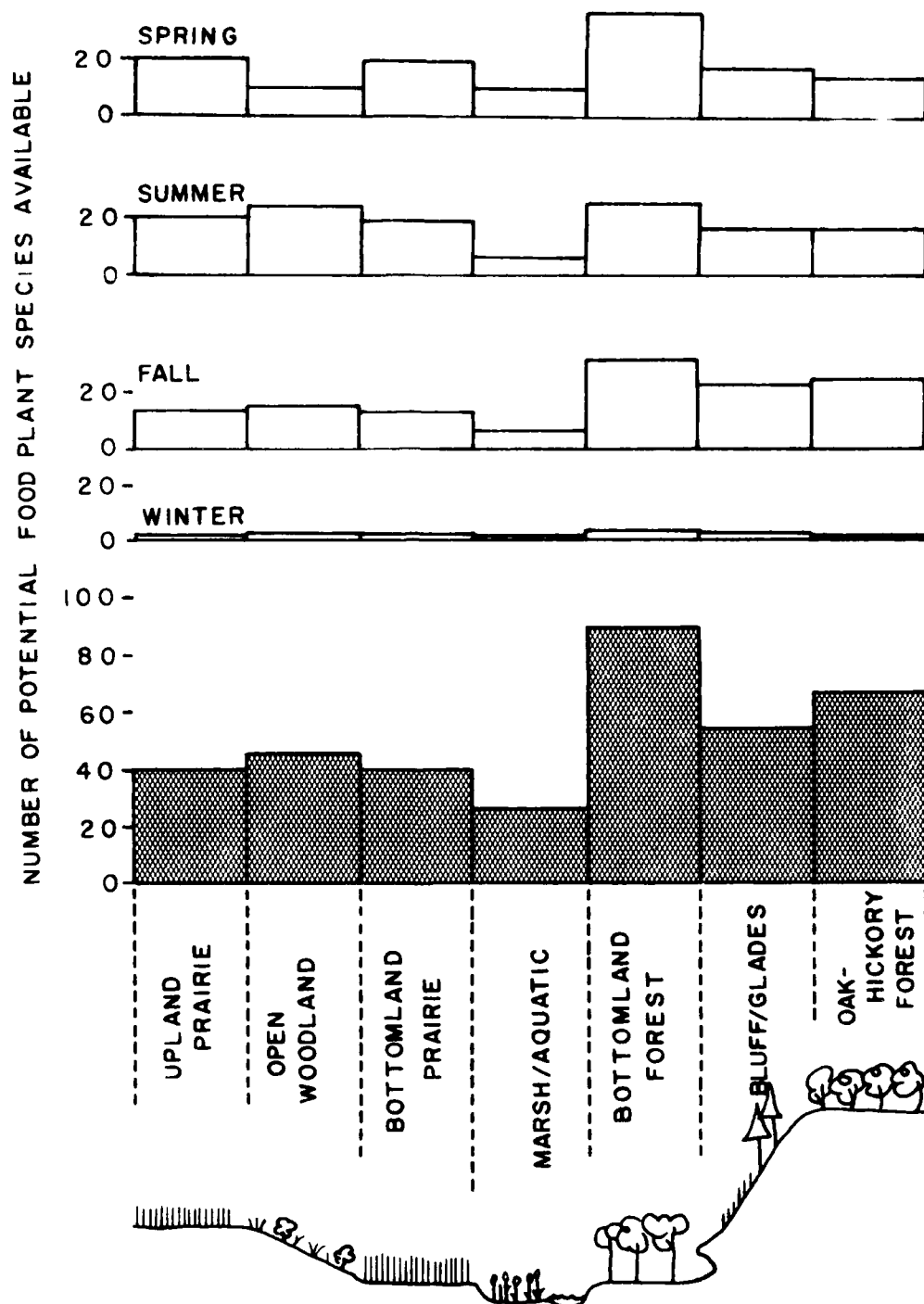


Figure 2.6. Seasonal and geographical diversity of potential food plants in the Truman Reservoir area.

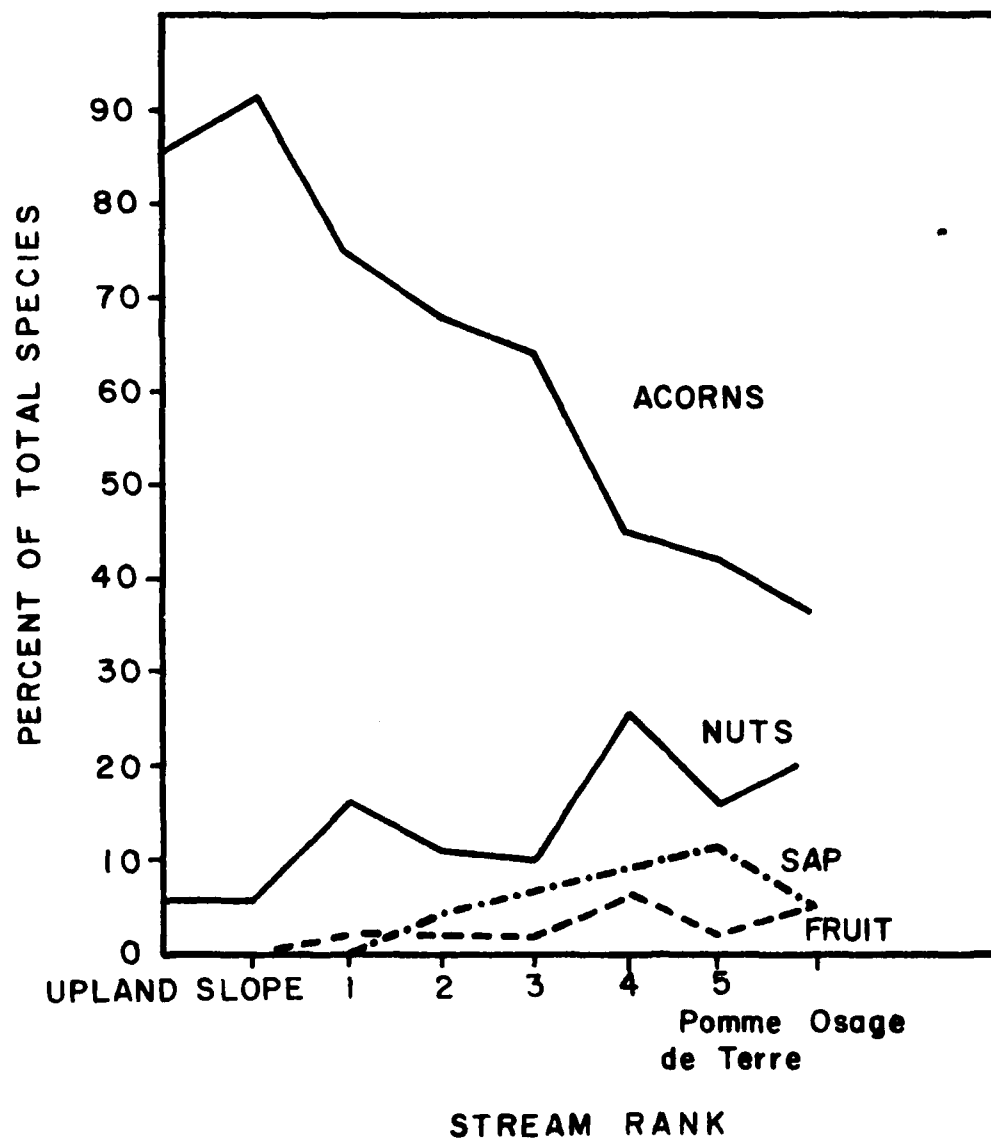


Figure 2.7. Relative percentage of different food producing tree species by stream rank and topographic zone.

tion types are fairly common in the western Ozarks region and plant diversity for the area is high. However, a few hundred miles to the west, forest is limited to valleys and slopes bordering floodplains and prairie covers the uplands; the number of potential food plants falls to 104. In addition, only about 50% of the woody bottomland food producing species occurring in the western Missouri Ozarks also occur in central Kansas. Assuming a proportional amount of these species were used for food, plants would have less than half the importance on the plains as in the woodland, and relatively more emphasis would need to be placed on either animal procurement or cultivation or certain prime food plants might have to be utilized to a greater degree, which is dangerous if that resource should fail. Similarly, if the floodplain forests of tributary streams dried up and the oak-hickory forest was reduced to open "barrens" and prairie, only 93 potential food plants common to these vegetation types would remain abundant, the rest occurring in highly localized habitats, if at all. Animal or cultivated foods would again need to be more heavily exploited.

WATER AS A LIMITING FACTOR

During much of the year in the prairie-forest ecotone, water alone is the limiting factor. The annual and seasonal distribution rainfall, the variation, and the precipitation/evaporation ratio are important factors in determining vegetation. Of particular importance are precipitation patterns. Whether rainfall occurs as frequent gentle rains during the growing season when vegetation cover is high or as brief heavy storms during the winter when there is no canopy and little ground cover to prevent erosion are critical factors in determining how much water is lost to runoff and how much accumulates in the soil. The lack of water may be aggravated by either lowered precipitation or by hotter temperatures, increased evaporation, and subsequently, less effective precipitation available for plant growth. The ground water reserves derived from snow and gentle winter rains are particularly important in the grasslands of the Middle West where total precipitation is less and it is not as well distributed throughout the year as it is in the forested regions.

Extreme drought would be the greatest hardship in the prairie-forest transition zone in terms of plant resources. The nuts and fruits of many species would shrivel and be dropped prematurely from the trees as a moisture conservation measure, and herbaceous plants would die or fail to even sprout since many require a minimum soil moisture content before germination takes place. The effects of drought would be felt least and latest by the plants of the bottomland communities, protected from the dessicating effects of sun and wind by valley slopes and growing in fine textured alluvial soils with relatively high water retaining capacities.

During a mild, or short term drought, diminished availability of plant foods normally collected on the slopes and uplands might be augmented by using a greater variety of the potential food plants available. During a severe or long term drought, it might be necessary to abandon camps along smaller tributary streams as such streams dried up and migrate to permanent water available at springs or larger streams where both plant and animal resources would be higher, at least during the worst seasons of the year.

Surface runoff increases with slope angle rapidly from 0-3° and only slightly thereafter (Durley and Hays 1932) so that it is greater in the Ozark Plateau region than on the relatively flat-lying plains to the west. However, the soils of plains are more finely textured, soil infiltration rates are lower and, consequently, ground water recharge is also lower than in the Ozark Highland (Skelton 1973:Pl 1; Stout and Hoffman 1973). In addition, many springs occur on the Ozark Plateau discharging from dolomite outcrops. The thick dolomite (1000-2000 feet) is capable of storing tremendous quantities of water, much of which is ultimately released through springs as delayed runoff. Although spring discharge is tied to precipitation, the rate of flow of springs is relatively uniform compared to that of streams. The base flow (sustained or fair-weather flow) of many streams in the Ozarks is almost entirely derived from springs, with some spring fed streams having the highest base flows in Missouri (Vineyard and Feder 1974:24).

Streamflow is also extremely sensitive to precipitation. While rainfall may decrease, evaporation and transpiration generally do not. As an example, if an area averages 40 inches of rainfall per year with evaporation and transpiration of 20 inches, 20 inches is left to be carried off by streamflow. If precipitation is decreased to 30 inches, while evaporation and transpiration rates remain the same, streamflow would be reduced to only 10 inches. Therefore, a 25% decrease in precipitation is magnified to a 50% decrease in streamflow (Stout and Hoffman 1973). Figure 2.8 shows the flow patterns of two similarly sized streams under different climatic regimes. In this diagram, the position of the curves gives the magnitude of the flow, and the slope is a measure of flow variability (Leopold, Wolman and Miller 1964:69). The Marais des Cygnes River has a much more variable flow and is dry about 20% of the time compared to Deer Creek in relatively moist Ohio with a more even flow and running perennially.

The delayed runoff caused by ground water storage and spring discharge and characteristic of many Ozark streams would ameliorate the effects of such short term precipitation deficits as displayed in the flow-duration curve for the Marais des Cygnes and the vegetation in such a bottomland situation would be much slower to feel the effects of drought than it would farther west in the Reservoir along streams with little or no delayed flow component.

PRECIPITATION, VEGETATION, AND RUNOFF

Leopold, Wolman and Miller (1964) note the obvious fact that if there is no precipitation, there will be no runoff and there will be no sediment removed by runoff from a drainage area. Further, in the absence of vegetation, successively higher precipitation will result in increased runoff and sediment yield. Vegetation also varies with quantity of precipitation. Langbein and Schumm (1958) were able to construct the quantitative relationship between annual precipitation and vegetation (Fig. 2.9) and between precipitation and sediment yield (Fig. 2.9). Agricultural studies have shown an increase in vegetation inhibits erosion, to the extent that erosion on fallow land or land in row crops is roughly 80 times that of grassland or forest (Leopold *et al.* 1964:47). If open desert scrub is roughly comparable to fallow or row cropland and

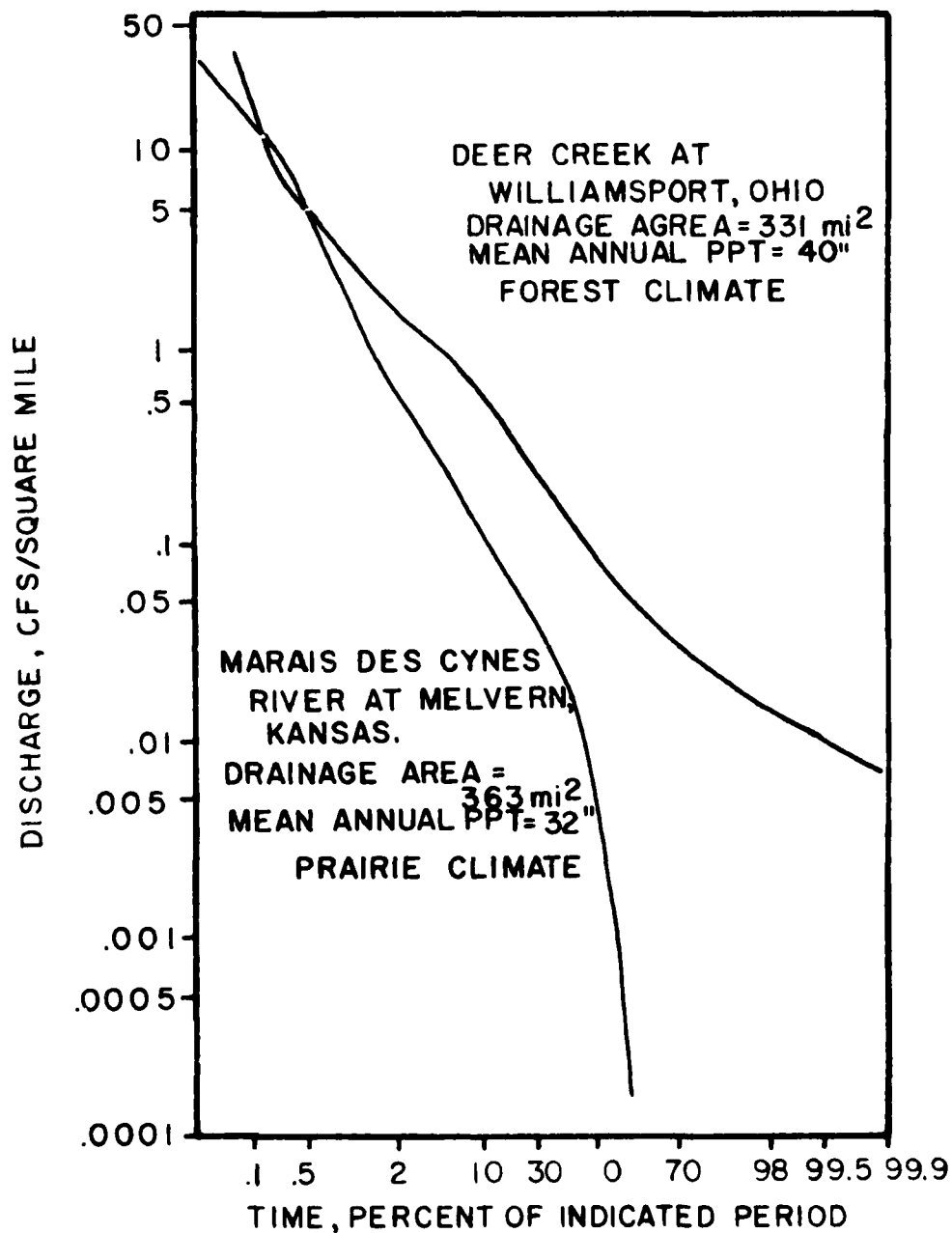


Figure 2.8. Flow-duration curve of mean daily flows for each of two rivers: Deer Creek at Williamsport, Ohio, and Marais des Cygnes River at Melvern, Kansas (from Leopold *et al.* 1964: Fig. 3-18).

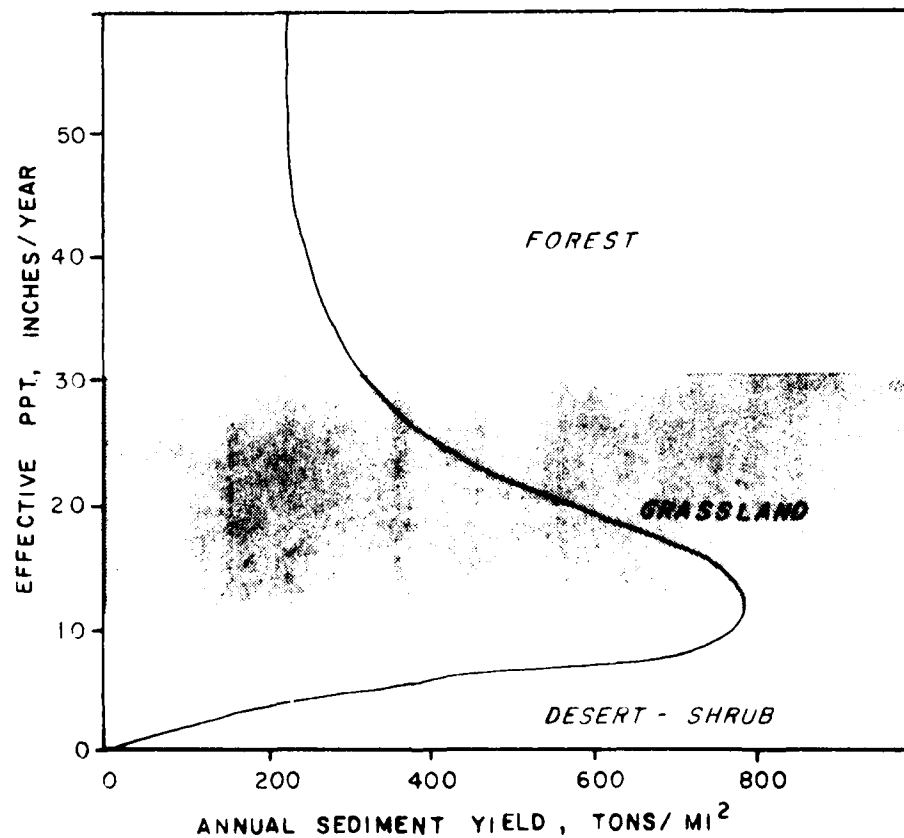
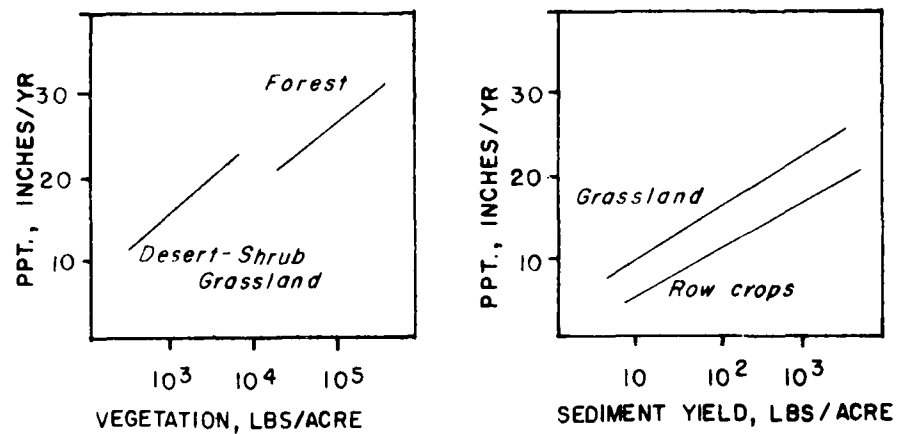


Figure 2.9. Quantitative relationship between vegetative growth (A) and sediment yield (B) and annual precipitation (adapted from Leopold *et al.* 1964, based on Langbein and Schumm 1958). (C) Climatic variation of yield of sediment as determined from records at sediment-measuring stations (Leopold *et al.* 1964).

pasture and forest comparable to the natural grassland and forest (Fig. 2.9) it can be expected at some point in the hypothetical relationship increasing precipitation and increasing sediment yield should reach a maximum and begin to decline because of the effect of vegetation on inhibiting runoff. This is shown in Figure 2.9. An effective precipitation rate of 15 inches corresponds roughly to central Kansas and Nebraska (Leopold *et al.* 1964:48).

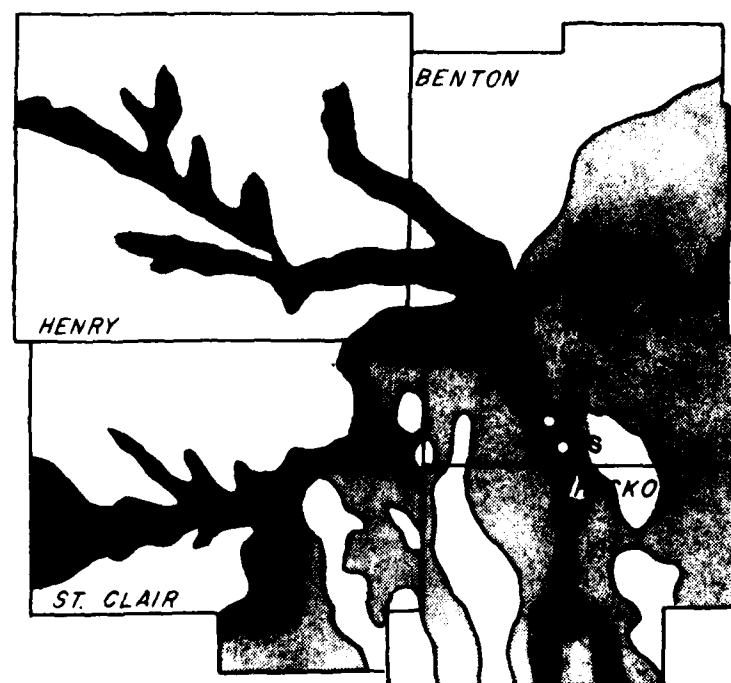
This model of the relationship between precipitation, vegetation and erosion is a concept that should be applicable to the western Missouri Ozarks. A reduction in precipitation large enough to affect stream flow and sediment load cannot occur without also affecting the vegetation.

As is evident from the stratigraphic sequence at Rodgers Shelter (discussed in Chapters 4 and 5), the early Holocene was a period of relatively high effective precipitation due to increased rainfall and/or cooler climatic conditions. It was also a period of relatively dense forest vegetation which probably indicates a fairly uniform distribution of rainfall throughout the year (Oosting 1956:131). The accumulation of relatively fine grained sediment (clay-silt) likewise suggests seasonal overflow produced by relatively moderate rather than catastrophic events. The decrease in precipitation which is displayed in decreased deposition rates after 8100 B.P. (Table 4.2) also acted to severely alter the nature of the vegetation. Effective precipitation must have been inadequate to continue to support the relatively dense forests which had existed previously and resulted instead in more open forests interspaced with dry adapted prairie species (King and Allen 1977).

The increase in precipitation occurring after about 4500 B.P. (King and Allen 1977) inevitably resulted in unprecedented high erosion rates because of the lag time in the recovery of the slope vegetation, which must itself have been further hampered by the rapid denudation rate. If this were not the case, and the presence of vegetation was not a mitigating influence, the early Holocene, characterized by relatively greater precipitation (King and Allen 1977), should have been a period of much greater hillslope denudation than is evident from the stratigraphic record.

CHANGES IN PLANT RESOURCE AVAILABILITY IN TIME AND SPACE

Based on the distribution of potential food plants and what we know of the relationship between vegetation and topography, soils and climate of the area, we have tried to approximate the distribution of plant resources under three sets of climatic conditions corresponding to the three main parts of the Holocene: the early cool, moist period; the dry Hypsithermal; and the late Holocene-Modern period (Figs. 2.10, 2.11, and 2.12). Throughout the history of man in the western Missouri Ozarks, the prime habitat, the one with the greatest plant diversity and abundance and the one in which plant food could be collected with the least amount of effort are the bottomlands of the major streams. The importance of the bottomland environment, measured in terms of relative plant diversity, increases under drier climatic conditions and decreases under moister ones with less environmental stress, while the extent of the habitat itself does just the reverse, becoming increasingly confined to the flood-



AVAILABLE FOOD PLANTS



>100 SPECIES



50-100 SPECIES



< 50 SPECIES

0 10 20 Km.

Figure 2.10. Diversity of food plants available during the fall at the time of the G.L.O. surveys in the early 1800's. Data on availability and distribution are based on King (1976) and on this report.

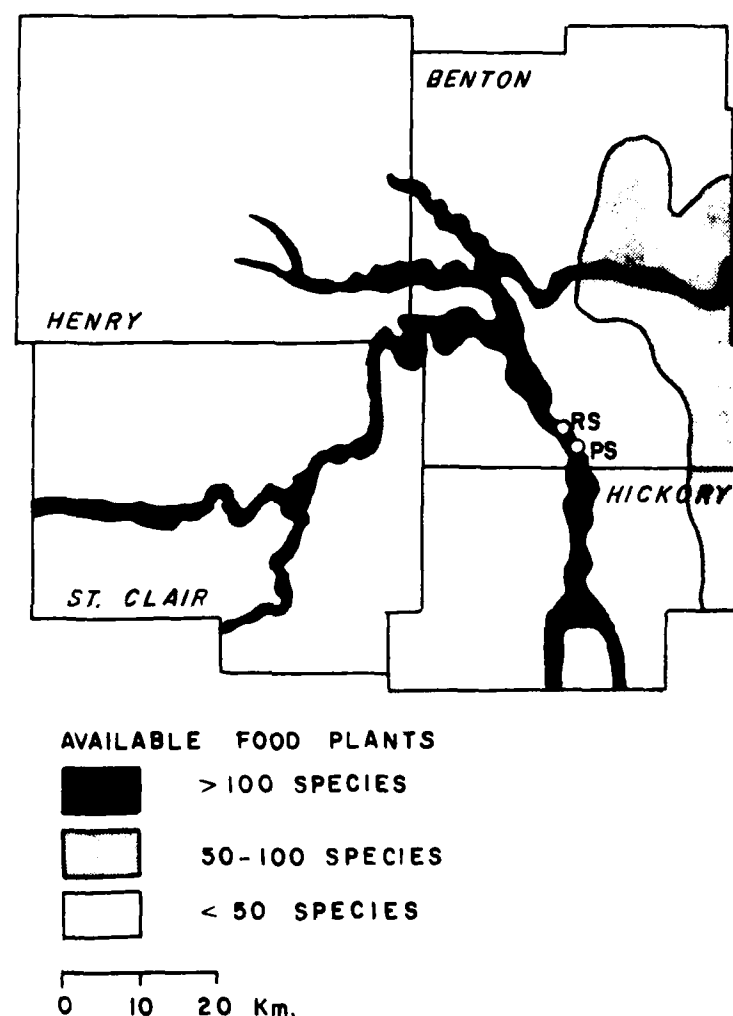


Figure 2.11. Projected diversity of food plants available during the fall for the mid-Holocene (Hypsithermal). Data on availability and distribution are based on King (1976). Distribution of vegetation types approximated from King and Allen (1977) and known relationships between vegetation and edaphic and topographic factors in this area.

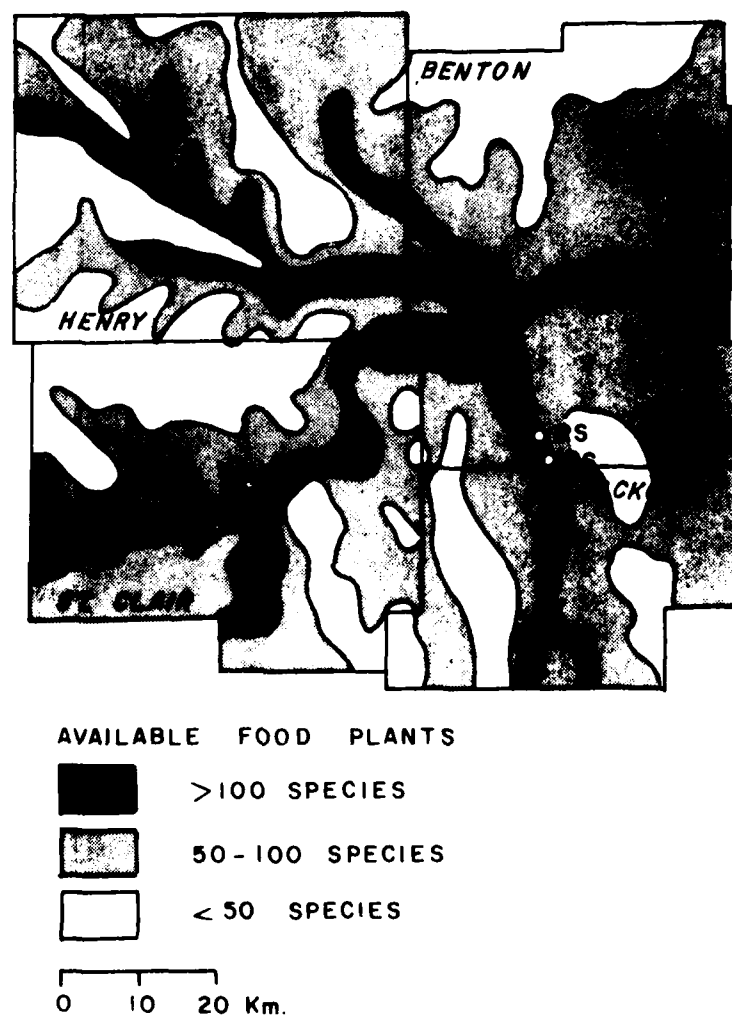


Figure 2.12. Projected diversity of food plants available during the fall for the early Holocene. Diversity data based on King (1976), distribution of vegetation types approximated from King and Allen (1977) and known relationships between vegetation and edaphic and topographic factors in this area.

plains of major streams during dry periods and extending farther up tributary valleys with periods of increased precipitation.

Plant resources formed only a fraction of the aboriginal diet and the relative importance of plant resources must also have varied by season. Lee (1968) stated that in the coniferous forest of North America, only 0-20% of the hunter-gatherer diet was plants.

The density of animal populations also corresponds to the available food. Smith (1975) predicted the density of one primary animal resource, deer, to be high in bottomlands during the spring and summer, cedar glades in the summer and the upland forest during the fall and winter providing there had been a good mast crop. Most other animal resources are either seasonally more abundant in bottomlands or entirely restricted to bottomland habitats (fish, turtles, mussels, waterfowl, wild turkey) and still others (deer, rabbits) prefer the edge habitat along a forest boundary or thickets, both of which are relatively well developed and species rich when occurring in floodplain situations.

Struever (1968) felt that an intensive exploitation system such as the Middle Woodland of the lower Illinois Valley could only occur where natural food products occur in concentrated populations and lend themselves to harvesting and are regularly renewed. Struever also stated that an environment that could support intensive harvesting would be best developed in certain broad river valleys with annual flooding and backwater lakes.

There is no evidence that the prehistoric Indians of western Missouri ever participated in intensive harvesting, and the resource base, even in the bottomland, would probably be inadequate for such a type of subsistence activity. Nonetheless, concentrated populations of easily gathered resources must always have been attractive and the resources chosen by Struever (1968) as most important (nuts and seeds, seeds of commensal plants, white-tailed deer, migratory waterfowl, and fish) are more abundant in the bottomlands of the Pomme de Terre as compared to the adjacent uplands as they are in the bottomlands of the Illinois River.

Wright (1976b) has shown that environmental change set the stage for plant domestication in the near East by producing optimal conditions for plant and animal domestication. It seems logical to suspect that environmental conditions combined with the decreasing abundance and diversity of potential food plants may have played an important role in developing the cultivation of native plants such as sunflower, chenopodium, or marshelder and in the adoption of such non-native cultigens as squash, corn or beans. The greater relative concentration of resources into certain habitats may have diminished the incentive to travel to other habitat types at the same time it was becoming necessary to exploit a greater percentage of the available resources and the impetus to adopt or develop cultigens may have been strong.

Although we have no evidence of the native cultigens in the Truman Reservoir, we have found remains of some of the oldest squash (*Cucurbita pepo*) and bottle gourd (*Legenaria siceraria*) known from eastern North America. This leads to the question of how unique the Pomme de Terre River valley is, in terms of being favorable for subsistence or incipient agriculture, compared to other parts of the Truman Reservoir.

The Pomme de Terre River, along with the Sac River, are the only major streams flowing into the Missouri River in the Truman Reservoir from the south, having originated in the Ozarks and deriving some percentage of their flow from springs. As a result, stream flow is probably somewhat more dependable here than in other streams in the reservoir, although the Pomme de Terre has been known to dry up during historic times. These are also the only two streams in the hilly ecotonal part of the reservoir and therefore the only ones having considerable upland forest habitat as well as bottomland forest and upland and bottomland prairie, and resultantly, the potential food plant diversity is higher along these streams than elsewhere in the Truman Reservoir. Animal diversity mirrors food availability and environmental diversity as well so that it too would be greater in an ecotonal region than in the prairie to the west or the closed deciduous forest to the east.

Considering specifically the area around Rodgers Shelter, it has within a 5 km radius as great a habitat diversity as anywhere in the Truman Reservoir and far greater than any upland or most bottomland sites. Because of the resource diversity around Rodgers Shelter, it is difficult to understand why it would have ever been abandoned for large portions of the year. If historic Indians can be used as a model, the inhabitants of Rodgers Shelter may have spent time at other sites within the immediate vicinity on the Pomme de Terre or sites farther distant where the hunting or fishing was better or some important plant resource more abundant (lotus, groundnut).

Archaeological remains have been recovered in four springs in the vicinity of Rodgers Shelter: Trolinger, Boney, Koch and Phillips. Of these, two, Phillips and Boney, have squash remains (King and McMillan 1975, Chomko and Crawford 1978, Wood 1976a) dated at 4380 ± 60 and 1920 ± 50 B.P., respectively. It appears that for at least the last 4000 years, areas around some of the springs in the vicinity of Rodgers Shelter were used for agriculture, a late spring-early fall activity. Although the squash may have been planted and then abandoned for the rest of the summer, the fact that they were planted adjacent to springs which would provide permanent water if the river ceased flowing during the late summer suggests there was some occupation around the springs for at least part of the year. It is possible that Phillips and Boney springs are unique in the prairie-forest ecotone of the western Missouri Ozarks. It is much more likely, however, based on distribution of plant resources and water that there are other similar sites around springs along the Pomme de Terre, the Sac and other drainages bordering the Ozarks. The Pomme de Terre valley is probably not unique in potential, only in the tremendous amount of study and research which has been involved in unraveling the mysteries of subsistence and settlement patterns, an opportunity which has itself been exceptional.

We have not attempted to reconstruct the precise vegetation assemblages that may once have occurred on some specific point. Rather, we have shown, on the basis of what we now know about the relationship between vegetation, bedrock, soils, topography, stream rank, and climate in the western Missouri Ozarks, seasonal and spatial patterns in the availability of plant resources and the directions in which changes in the distributions of those resources may have occurred through time.

Hopefully, this knowledge will enable us to better interpret the subsistence activities that took place at Rodgers Shelter, not just from the floral and faunal remains, but also from the cultural material as well.

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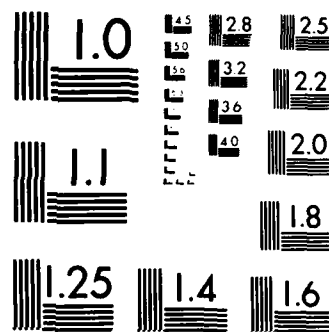
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CHAPTER 3

RODGERS SHELTER: AN EXAMPLE OF DEEP SITE SAMPLING

Marvin Kay

Brown (1975) recently observed that deeply stratified sites are a mixed blessing even though some of the most important archaeological sequences are developed from excavation of multilayered sites with long histories. Their excavation is neither simple, fast nor inexpensive; involves a departure from probabilistic research design (Binford 1964; Asch 1975); and has inherent limitations even under the best of research conditions (Brown 1975:155; Chapman 1977:3-11). Deeply buried sites often record variable configurations in community layout, differences in site function, intensity or season of use, depositional histories and differential preservation. The orientation and scale of excavation, recording and recovery techniques are equally instrumental in evaluating these differences among superimposed archaeological components, much as conventional sampling techniques are for surface sites. But recovery from deeply buried strata is largely predetermined by the initial size of the excavation; total excavation is virtually an impossibility. Even when artifact yield is large, culturally diagnostic items are often infrequent or absent. In these cases it is difficult, if not impossible, to infer more than the existence and age of an occupation in a specific stratum. Thus it is no wonder that sampling strategies are a major preoccupation of deep site archaeologists.

Major advances in deep site sampling technique and strategy in eastern North America have come about in the past decade, largely through programs of deep site excavation and analysis. Rodgers Shelter is a primary example.

During the 1960's, Rodgers Shelter was a focus of massive excavation in the lower Pomme de Terre valley, Missouri (Part IV, Wood and McMillan 1976), and supplementary excavations were conducted in 1974 and 1976. Excavation of its alluvial deposits that exceed 9 m in thickness and contain spatially extensive units has in no small part contributed to our knowledge of deep site sampling prerequisites. Though there is no single formula, the purpose of deep site sampling is to attempt to insure comparability of data from sequentially related components at minimum cost and maximum safety. McMillan (1976a:117-118) succinctly summarized the inception of the sampling program for Rodgers Shelter as:

During the same summer [1964], one test pit (230NW100) was excavated for depth in an attempt to reach bedrock. It was in this pit that the earlier horizons that had come to light in 1963 were discovered. Upon learning that parts of the site were at least 9 m deep it became obvious that it would be impossible to excavate Rodgers Shelter totally, within the constraints of time and resources--as well as good judgment. Two problems arose then, that of sampling and the complex logistics of deep site excavation. To

accommodate both sampling and excavation it was believed that the best strategy would be that of large block excavation.

McMillan's decision to excavate a test square to bedrock and its fortunate location illustrate a basic axiom of deep site sampling: that prerequisite to systematic site excavation is detailed knowledge of the cultural and physical stratigraphy.

At Rodgers Shelter this knowledge led to a logical progression of systematic excavation of sequential preceramic and ceramic complexes from a large "block" centered on the shelter and the terrace to its immediate front (Fig. 3.1). Ultimately, excavation was continued over seven summer field seasons, starting in 1963 and ending in 1976. This time marks major changes in research orientation, strategy and its execution that have obvious effects on the kinds and quantities of samples obtained from Rodgers Shelter. Although the general sampling design for the 1960's is described by McMillan (1976a), it will be of value to review the overall history of Rodgers Shelter data collection as it has a direct bearing on studies subsequently presented in this report.

SITE SETTING

The shelter, a resistant tongue of Ordovician Jefferson City Quarry Ledge dolomite, is at the base of a south-facing bluff overlooking an intermediate terrace approximately 90 m north of the Pomme de Terre in south central Benton County, Missouri. The overhang provides shelter for 24.5 m along the bluff; near the center of this span the maximum width is reached between the back wall and the dripline, a distance of 8 m. Approximately 102 m² of floor space is nominally protected from precipitation, though the deposits underneath the shelter become saturated after prolonged or intense rain.

Terrace 1b (Haynes 1976), the Rodgers terrace, parallels the bluff on either side of the shelter for a total of about 270 m, has an elevation of 213 m (about 700 feet) above mean sea level, and slopes gently to the southwest. Dissecting the hillslope above the terrace are two hollows that issue onto and deeply trench the terrace to the east and west of the shelter. The southern edge of the terrace is truncated by a recent channel scar, and abuts against T-0.

RESEARCH HISTORY

Rodgers Shelter was discovered in the spring of 1962 by Rolland E. Pangborn of the University of Missouri-Columbia, and, subsequently was designated 23BE125 by the Missouri Archaeological Survey. The Shelter was named for its owner, Jack Rodgers, though previously it has been known as Rash Bluff or Cedar Bluff. In the late 1960's the federal government purchased the property in preparation for Harry S. Truman Reservoir. Shortly thereafter, Rodgers Shelter was placed on the National Register of Historic Places.

Fieldwork began in 1963, continued for thirteen months over that and the next four summers, was renewed in 1974 for a single month, and terminated with a three month field season in the summer of 1976. The first excavations were by William E. Sudderth and Sidney Denny, graduate



Figure 3.1. View of the main excavation, Rodgers Shelter, 1967.

students at the University of Missouri-Columbia, of a thirty-five feet by five feet trench perpendicular to the bluff at the approximate midpoint of the overhang. The excavation in five-foot squares penetrated only the upper sediments of the terrace, later defined as Stratum 4, and established that the site had sufficient depth to potentially resolve certain chronological problems evident at other multicomponent Ozark Highland sites with collapsed stratigraphy. With this in mind excavations were planned for the following summer.

These excavations established that the culture-bearing deposits were far deeper than expected, but, as McMillan (1976a:112) relates, "it was 1965 before the earliest cultural horizon was found, 9 m below the surface near the base of the terrace." McMillan directed the field work in 1964, all subsequent field work in the 1960's, and has maintained an active supervisory role in the 1970's research. Excavations in 1974 were conducted by Kerry McGrath, under W. Raymond Wood's direction. And, Kay assumed charge of the research program in 1975.

Originally Carl H. Chapman was responsible for reservoir research, a responsibility assumed by W. Raymond Wood in 1965. Project funding for the first three years was through contracts between the University of Missouri and the National Park Service; but once it was realized that "massive excavations would be needed to reach the lower horizons, funds were supplied by three successive National Science Foundation research grants (GS-1185, GS-1604, GS-2112) awarded to Wood" (McMillan 1976a:112), allowing completion of the 1960's research. McMillan (1971, 1976b), and Ahler and McMillan (1976) have developed preliminary cultural and environmental models from this research.

The 1974 excavations were supported by a contract between the Illinois State Museum Society and the National Park Service though the contract was primarily for research at Phillips Spring. A final contract between the Illinois State Museum Society and the Corps of Engineers has supported the project since 1975 (Table 3.1).

TABLE 3.1

Record of Excavations at Rodgers Shelter, Missouri

Date	Field Supervisor	Director	Sponsoring Agency
June 1963	Suderth and Denny	Chapman	N.P.S.*
August 1964	McMillan	Chapman	N.P.S.
July-August 1965	McMillan	Wood	N.P.S.
June-August 1966	McMillan	Wood	N.S.F. ⁰
June-August 1967	McMillan	Wood	N.S.F.
June-August 1968	McMillan	Wood	N.S.F.
July 1974	McGrath	Wood	N.P.S.
July-September 1976	Kay	McMillan	C.E.+

* National Park Service
⁰ National Science Foundation
+ Corps of Engineers

SAMPLING

In 1964 an English grid system oriented to magnetic north was established and has been used for horizontal excavation control. Grid coordinates were recorded in increments of feet, tenths of feet and inches north and west of an arbitrary reference point established off the site boundary, and excavation was mainly within five-foot grid squares. An example would be that of a square at the intersection of 230 North and 100 West grid lines, recorded as grid square 230NW100. The point of maximum shelter overhang was established along the 100 West grid line, and the 1963 excavations occupied the grid space between the 95 West and 100 West lines. The 1974 excavations near the west end of the dripline underneath the shelter were established without reference to this grid because of an inability to relocate buried grid markers; three contiguous and partially overlapping excavations units were assigned labels A, B, and C. In 1976 buried grid markers were re-excavated, and the original grid was reestablished; the 1974 excavation was located according to this grid as well.

The English system of measurement, as it pertains to length, distance or area, was initially used at Rodgers Shelter. Although there are obvious disadvantages that result when the English and metric system are mixed, it was felt that an even greater disadvantage would be to supplant the English system at Rodgers by the metric system. Also most items of equipment used to size-grade debris were referenced to the English system. Thus in this report the English system is used to describe grid locations, and depth at Rodgers Shelter and also size-grading equipment. The Phillips Spring excavations have consistently employed the metric system, with the exception of our standard size-grading equipment. Comparisons of excavation area for the two sites are given in the metric system.

Vertical control was first recorded as depths below ground surface, but once the extent of the culture-bearing deposits was realized in 1965, an arbitrary vertical datum was established and measurements were taken with a farmer's level and stadia rod. Depth recordings in 1974 were from a horizontal plane that corresponded with the original ground level. In 1976 the original vertical datum was redefined and datum depths of the 1974 excavations were taken also.

Mechanical excavation assistance was of three kinds. A bulldozer was employed to excavate a trench along the 100 West line to the river, both to provide stratigraphic profiles and to facilitate removal of hand excavated sediments from deeper levels. The site was opened with a bulldozer. In 1968, and again in 1976, stratigraphic profiles were cut with a backhoe. Overburden in front of the shelter and disturbed deposits beneath the overhang were removed in 1968 with a backhoe to complete hand excavation of more deeply buried cultural horizons. A truck-mounted hydraulic soil probe and a track-mounted versadrill were used in 1975 and 1976 to auger to bedrock and take continuous soil cores for stratigraphic and mechanical soils analyses.

Excavation has been conducted beneath the overhang, to its immediate front and across the terrace. To facilitate intrasite analysis and description, a four part division of the site area has been followed

(McMillan 1976a:119):

the *shelter*: the protected area beneath the overhang.
the *main excavation*: that portion of the terrace immediately
in front of the overhang.
the *terrace*: the area west of the main excavation
extending to the ravine.
the *west terrace*: that portion of T-1b west of the ravine.

These areas are labeled in Figure 3.2.

From 1963 to 1968 contiguous five-foot squares were excavated in .5-foot thick units, ultimately resulting in removal to bedrock of a large "block" beneath and to the immediate front of the overhang. The maximum dimensions of this area are 18.3 m by 12.2 m, roughly 151 m² being the maximum possible horizontal coverage for a cultural horizon. This block, or *main excavation area*, represents our most comprehensive data set from Rodgers Shelter. A sequential series of preceramic and ceramic complexes is readily recognized though Dalton and later Archaic complexes predominate in four major stratigraphic units, designated sequentially Stratum 1 through 4 (Fig. 3.2b). This area was also a major loci of site activity.

Variable coverage and control, however, occurred within the main excavation area because of four factors. First, rodent and recent disturbance of the upper sediments beneath the overhang was extensive, resulting in the wholesale removal and discarding of much of the Stratum 4 shelter deposits. Then too, slumpage (usually minor) of standing profiles occurred, resulting in an unpredictable loss. Third, in 1968, all of the upper deposits were mechanically removed from a fifteen-foot square (225NW80) in an attempt to quickly excavate the basal Dalton horizon. And, lastly, there was an evolution of more sophisticated and comprehensive recovery techniques over this five year period.

In 1968, these excavations were supplemented by a checkerboard pattern of test pits (five-foot squares) on the terrace, backhoe trenches and a 10-foot square approximately 100 m west of the shelter. These excavations delineated an essentially identical stratigraphic profile to that of the main excavation area and established that site activity was widespread, extending across the ravine and onto the west terrace.

Pollen samples were taken from standing profiles of the main excavation area as well during the 1960's. Though present, pollen is unfortunately highly eroded and unidentifiable.

The final excavation efforts, including the 1974 work, were attempted because we recognized certain inconsistencies in data recovery, particularly of microscale remains. Virtually no microvertebrate elements had been recovered from the upper sediments. And, it had been impossible to assess seasonal factors in site use that depend, in part, on examination of vertebrate and ethnobotanical remains (Munson *et al.* 1971). Charcoal recovery had also plagued us, and it had not been possible to submit samples for radiometric dating of the upper strata or to complete a close-interval dating program for T-1b as a whole. Moreover, no assessment of natural rock debris had been attempted, largely because these data had been haphazardly recorded or discarded in the initial dry screening. Farrand (1975) has shown the utility of natural rock debris analysis for paleoenvironmental reconstruction. Pedological

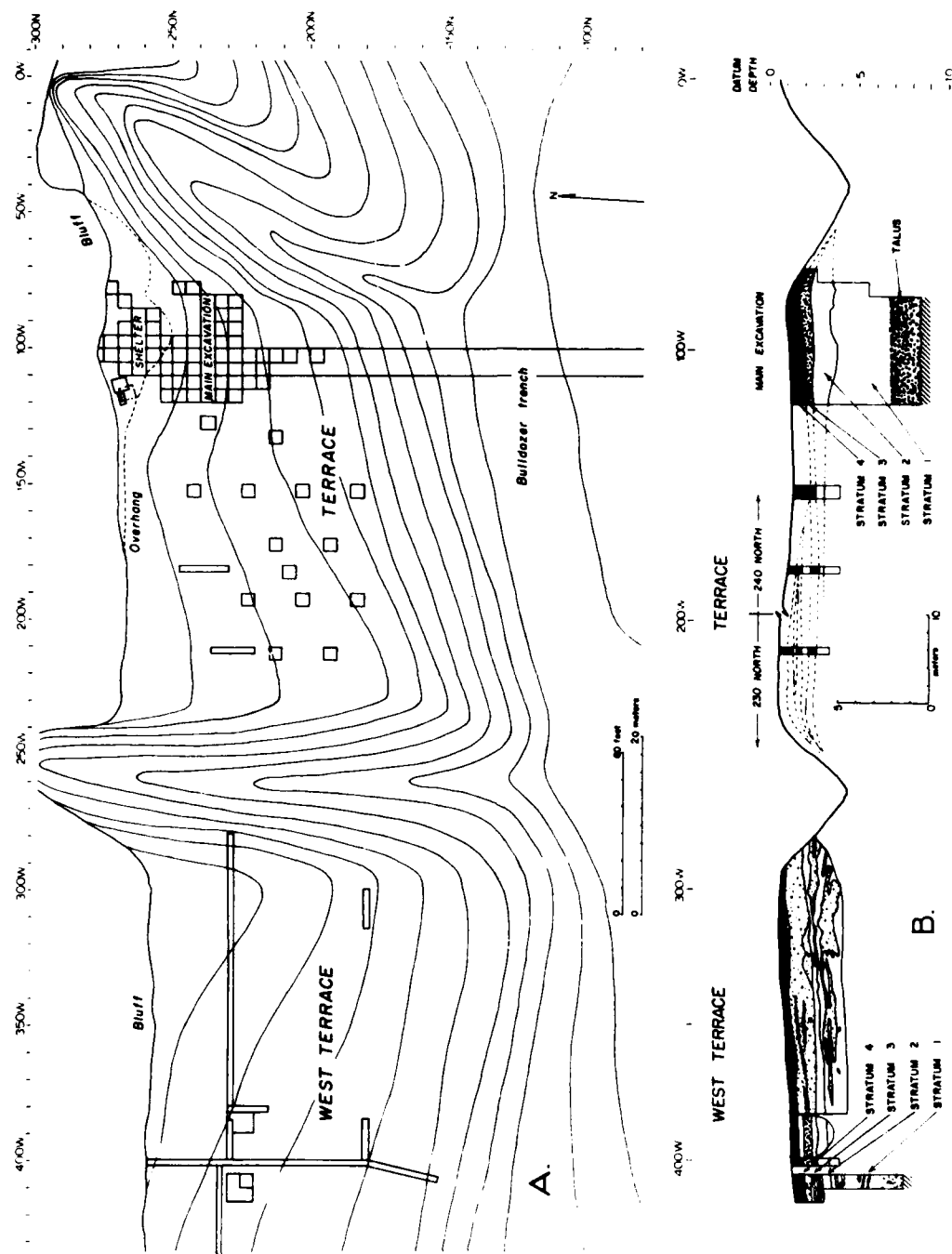


Figure 3.2. a. Excavation plan of Rodgers Shelter, contour interval equals 2 feet; b. Terrace-lb stratigraphy along 230N and 240N lines.

descriptions of the standing profiles were needed as well to assist the evaluation of Rodgers terrace landscape stability, initiated by Ahler (1973a,b; 1976). Nor had bulk samples been taken for gastropods, which occur in numbers and are sensitive to climatic or environmental change (Baerreis 1973). These excavations solved these problems and contributed data from contrastive site areas.

The 1974 excavations attempted to comprehensively sample microscale elements and charcoal from a five-foot square beneath the overhang. Because of rodent disturbance, previous backfilling and recent vandalism, it was impossible to initially remove a volume of undisturbed sediments equivalent to the volume of a five-foot square, excavated in .5-foot levels, from a single five-foot square. Unit A, a five-foot square, and a contiguous two feet by five feet rectangle (unit B) were excavated in arbitrary .5-foot thick levels to a depth of thirty inches below ground level, the transition zone between Stratum 4 and Stratum 3 where a human burial was encountered. To remove the burial, a new five-foot square (unit C) was initiated and then continued, thereby excavating Stratum 3 and lower sediments. This square partially overlaps with the two superior excavation units. Excavation of square C terminated in a zone of massive rock fall roughly 5.5 feet below the ground surface. General excavation procedures followed those for units A and B. Square A overlaps primarily with the five-foot grid square 265NW110. Squares B and C are mainly within five-foot grid square 265NW115. Note that in Figure 3.2 Square C is indicated by dotted lines.

Preceding the final hand excavations were the cutting (1975) of three backhoe trenches and a systematic soil probing effort on the west terrace that further defined the stratigraphy. Two backhoe trenches were dug on either side of the ten-foot square excavated in 1968. The east trench connected with both the square and a 1968 backhoe cut in the west ravine; unfortunately, the west trench collapsed before it could be recorded. A third trench intersected the west edge of the 1968 square and cut a profile perpendicular to the bluff and the other trenches across T-1b along approximately the 400W line. Maximum depth of these trenches was 4.25 m; and the two that paralleled the bluff were generally on the order of 3.5 m deep. The soil probes that continued to bedrock were selectively placed west of the third trench and also parallel to the trench east of the 1968 square, and afforded precise stratigraphic control used in placing the west terrace excavation.

A second ten-foot square, subdivided into five-foot square excavation units, was initiated on the west terrace approximately three feet west of the third backhoe trench where two soil probes had been taken to bedrock, providing a very reliable stratigraphic summary. Controlled excavation of .25-foot thick levels of all Stratum 4 sediments were completed in the excavation block and for Stratum 3 in the five-foot square 220NW405, the southeast excavation unit. The rest of the Stratum 3 fill, essentially sterile alluvial silt and gravel, was removed in mass from the other excavation units to establish an excavation platform to facilitate work in square 220NW405. Ultimately, this southeast square was excavated to bedrock (Fig. 3.3) in arbitrary or natural levels, generally of no greater than .25-foot thickness.

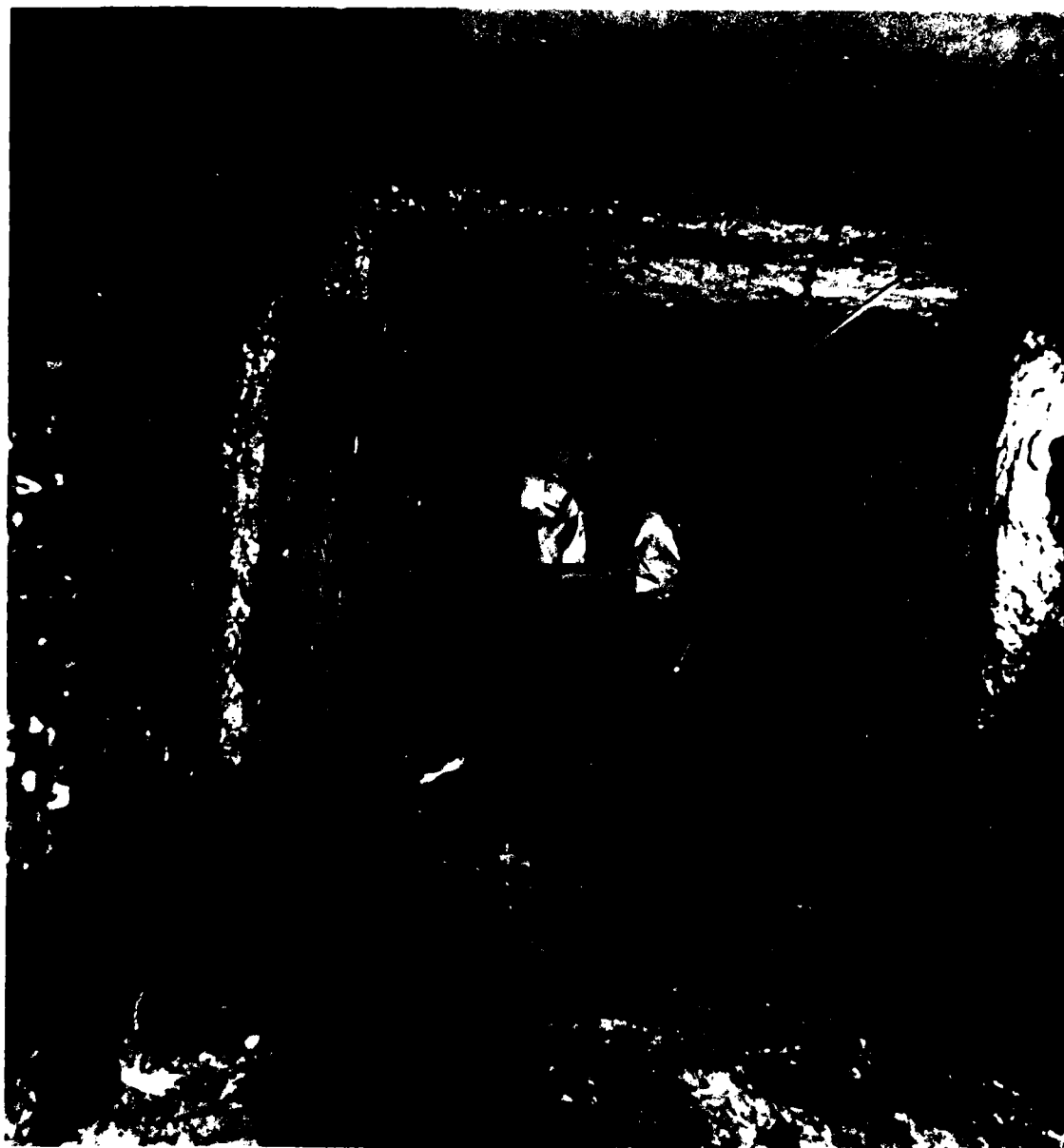


Figure 3.3. Crew member (John Nylander) standing in nearly complete excavation of 220NW405.

Concurrent with this operation, a second stratigraphic column, equivalent to a five-foot square (Fig. 3.4), was taken to bedrock on the east side of the main excavation area. Identical excavation controls were followed. However, much of the excavation was along a standing profile and it was a somewhat simpler operation.

Bulk matrix samples (approximately 2-1.) were also taken from excavation walls for gastropod recovery. These samples correspond with the primarily arbitrary excavation levels of .25-foot thickness and were taken from the ground surface to bedrock of both 1976 excavations.

It was desired as well to take complete soil monoliths of both 1976 excavations. This, however, was not done due to inclement weather and lack of time at the end of the field season. As had been done previously, soil samples were taken from each excavation level.

Throughout the project history recording procedures have been generally consistent. Features have been photographed and drawn in planar or cross sectional views; cataloged notation has been entered for items from provenienced excavation, from general midden deposits, or surface finds; two dimensional drawings have been made of standing profiles, or have been reconstructed at five-foot intervals from excavation summaries for the main excavation areas.

Recording procedures in 1976 differed in certain details from that of preceding field seasons. Points in a floor diagram were triangulated from two grid corners, thus reducing errors inherent in approximating right angles. The strike and dip was also recorded for *in situ* items. Photographic mosaics of profiles (Fig. 3.5) were also taken as a permanent profile record. This technique has been further perfected by subsequent project work at Phillips Spring.

Though there has been a consistent attempt to screen excavated sediments, with the exception of essentially sterile units such as Stratum 3 or sections of Stratum 1, there have been major changes in effective recovery, brought about by a shift from dry screening to water screening and flotation. Sediments were predominately dry screened through 1/2-inch wire mesh in the 1960's. Starting in 1965, a one-foot block was saved for water screening (through 1/8-inch wire mesh) from each grid square, greatly enhancing recovery of microelements. McMillan (1976a:120) illustrates this operation. In 1974, all sediments were subjected to water flotation, using techniques pioneered by Struever (1968), and reasonably accurate volumetric controls were maintained. 1976 marked the culmination of these efforts, with a combination of size-graded water screens and flotation techniques (Fig. 3.6) that allowed for near-total processing of excavated sediments. Size grades were graduated from a maximum of 3-inch to 1/16-inch wire mesh, and sediments remaining in the 1/16-inch screen or bulk sediment samples were floated. These techniques have been improved upon since, primarily through the addition of an air compressor to the flotation system which is patterned after one by Watson (1976). Trisodium phosphate, a clay dispersant that does not contaminate C¹⁴ samples, generally was needed to facilitate the 1976 water screening and flotation processes.

Water screening and flotation allowed for systematic, consistent collection of all debris with a minimum of breakage and was far superior to previous recovery attempts. Nonetheless, these procedures are not



Figure 3.4. Excavation of stratigraphic column near overhang, 1976.



Figure 3.5. Photomosaic of main excavation area profile, 1976.



Figure 3.6. The main excavation processing operation, 1976.

as efficient or economical as they might be. The size grade screens were of a standard sieve size, an additional expense that proved unnecessary as virtually all material had to be resized later. Though not done, in retrospect it would be useful to calibrate the flotation chambers to determine effective recovery of the smallest seeds for a given mesh size. I do not feel this has had any qualitative impact on the ethnobotanical studies, in as much as both seeds and gastropods smaller than 1/16-inch (1.59 mm) were consistently recovered in large numbers. But calibration could be effected easily by adding known amounts of size-graded iron filings to floated sediments which then could be magnetically extracted and quantified on a per-unit-volume basis.

As operationalized in 1976, these procedures would be prohibitive on a larger scale excavation. Subsequently, we have modified the recovery system for the large block excavation of Phillips Spring by: (i) restricting water screening to size grades greater than 1/4-inch for general level excavation sediments; (ii) taking a flotation block of 10 cm³ from each 10 cm level; (iii) floating all feature or possible feature sediments. Though there is a necessary loss of material in the smallest size grades, this approach is an efficient, flexible compromise that allows for the estimation of small scale debris densities. I may note as well that bias in the collection of certain classes of debris at the expense of others is effectively eliminated by these procedures, though at Rodgers Shelter modern botanical contaminants were introduced by using Pomme de Terre River water. These are easily differentiated from the charred ethnobotanical materials but require additional processing time. At Phillips Spring, the artesian discharge was tapped in the recovery operation, insuring an uncontaminated source of water.

Table 3.2 summarizes effective recovery for major classes of debris from Rodgers Shelter by field season. With respect to Table 3.2, a few items require further clarification. Recovery of charcoal, even in 1976, was not truly total. Sediment compaction, soil leaching and differential preservation with depth have all contributed to a nonuniform distribution of charcoal, so that the older and deeper deposits contain less than do the upper strata, especially Stratum 4. Charcoal from units beneath Stratum 4 exists as either small isolated flecks or as primary concentrated fire remnants, and these charcoal concentrations have been used exclusively in the 1960's radiocarbon dating of Strata 1-3. 1974 and 1976 recovery afforded collection of small scale charcoal, sufficient for additional radiocarbon dating of all strata. Dry screening in the 1960's generally used a mesh size of 1/2-inch square. Nontool elements, including lithic debitage, were selectively but not systematically picked, resulting in considerable potential bias. Unifacial tools, generally fashioned from flake blanks, were similarly collected in the dry screen operations. And the same is true for vertebrate bone debris. Because of this, debris classes labeled in Table 3.2 other than "probably biased recovery but still usable for distributional studies" or "essentially unbiased recovery" have been eliminated from most quantitative debris studies -- the exception being identifiable faunal remains.

TABLE 3.2

Effective Recovery* of Major Debris Classes from Rodgers Shelter

Debris Classes	Field Season							
	1963	1964	1965	1966	1967	1968	1974	1976
Natural Rock	--	--	--	--	--	--	--	+
Minerals	?	?/+	?/+	?/+	?/+	?/+	+	+
Ground Stone	?	+	+	+	+	+	+	+
Bifacial Tools	?	+	+	+	+	+	+	+
Unifacial Tools	?	?	?	?	?	?	+	+
Hammerstones	?	+	+	+	+	+	+	+
Cores	?	+	+	+	+	+	+	+
Lithic Debitage I ^a	?	?	?	?	?	?	+	+
Lithic Debitage II ^b	--	--	--	--	--	--	+	+
Ceramics	?	?	?	?	?	?	?	--
Bone Tools	?	?/+	?/+	?/+	?/+	?/+	+	+
Faunal Remains I	?	?/+	?/+	?/+	?/+	?/+	+	+
Faunal Remains II	--	--	?	?	?	?	+	+
Ethnobotanical Remains	--	?	?	?	?	?	+	+
Charcoal	--	?/+	?/+	?/+	?/+	?/+	?/+	?/+

^a greater than 1/2-inch size grade^b less than 1/2-inch size grade

- * -- not present or not recovered
 ? present, but with biased recovery
 ?/+ probably biased recovery but still usable for distributional studies
 + essentially unbiased recovery

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CHAPTER 4

STRATIGRAPHIC STUDIES AT RODGERS SHELTER

Marvin Kay

Rodgers is the type site of the Rodgers terrace, or Terrace-1b, a Holocene terrace now well defined in the lower Pomme de Terre valley (Haynes 1976; 1977:24). Haynes (1976:59) has correlated the inception of Terrace-1b, at the end of the Pleistocene but before 10,500 years ago, with the Valderan substage [now renamed Greatlakean; Evanston *et al.* 1976], illustrating a subcontinental correspondence in aggradation at the end of Wisconsinan glaciation. The terrace records a varied depositional history that bears directly on cultural interpretations of Rodgers Shelter. And terrace stratigraphy at Rodgers Shelter is a subject of considerable interest to archeologists, geomorphologists and pedologists. Major depositional units occur as four natural strata, sequentially labeled Stratum 1 through 4. These units are largely continuous across Terrace-1b at Rodgers Shelter (Fig. 4.2b) and intra-stratigraphic subdivisions of varying complexity are common. Ahler (1973b; 1976) further divides the four strata into eleven sedimentary units, most of which were apparent in the field, that express a multifaceted history of overbank and alluvial fan deposition, frost action along the southerly facing bluff and episodes of terrace degradation. About 500 B.P. the terrace was cut by a Pomme de Terre channel.

The stratigraphic studies of the Rodgers terrace have attempted to (i) systematically order the cultural deposits to facilitate their analysis and (ii) interpret the sedimentary record as an expression of prevailing environmental or climatic conditions. McMillan (1971:71-72) first devised series of correlative levels for the four major excavation areas as the primary means of ordering excavation units, an approach which has been continued. Ahler (1973a and b; 1976) further elaborated on Terrace-1b stratigraphy at Rodgers through mechanical (textural) and chemical analyses of sediments, formalized seminal aspects of a model of Holocene environmental and climatic change, and documented problems in stratigraphic interpretation that required further study. Subsequent research has re-examined the Rodgers stratigraphy in light of Ahler's efforts and has completed the C¹⁴ dating of terrace sediments. This and the next chapter are an essential update of these data.

If for no other reason, data not available to the earlier studies, now collected, afford a new chance to reconsider environmental and stratigraphic interpretations. This chapter deals with the stratigraphy and is divided into sections that describe the history of stratigraphic interpretations, radiocarbon dating and, given all the evidence, what is the most satisfactory assessment of intrasite correlations. The following chapter begins an evaluation of Holocene environmental and climatic change, in light of Ahler's work and new data.



RADIOCARBON DATING

Thirty-two charcoal samples have been radiometrically dated. Eleven are from the 1960's excavations. Ahler (1976:124, Fig. 8.2) projects the locations of ten of these along the 100W profile of the shelter and main excavation; the final date of 430 ± 100 B.P. (A-867) is from the recent channel fill that truncates the Rodgers terrace. With the exception of the latter, the 1960's dates are on charcoal from hearth features, or from charcoal concentrations from Strata 1 to 3. The twenty-one new dates include nine from the 1974 and twelve from the 1976 excavations beneath the shelter, to its front or on the west terrace. Of these, one is from a non-cultural charcoal concentration in Stratum 1. The remainder are from charcoal collected in the flotation of general excavation matrix from Strata 2 (three dates), the contact between Strata 3 and 4 (three dates), and Stratum 4 (fourteen dates). All radiocarbon dates are reported (Table 4.1) with reference to $t_{1/2} = 5568$ years, the conventional Libby half-life. Table 4.2 summarizes rates of sediment deposition on Terrace 1b, based on a comparison of the datum depths of radiocarbon dates from the shelter and main excavation areas of Rodgers Shelter.

Rodgers Shelter radiocarbon dating provides one of the oldest, longest and most complete absolute chronology of any archaeological site in eastern North America. The few stratigraphically reversed dates are truly minor and do not upset the reliability of the chronology. These include: M-2333 ($10,200 \pm 330$ B.P.) and ISGS-48 ($10,530 \pm 650$ B.P.), the basal dates on two stratigraphically separate hearths (respectively 8.98 m and 8.53 m below datum); SMU-478 (2247 ± 73 B.P.) and SMU-454 (2349 ± 76 B.P.) (respectively, 1.28 m and 1.20 m below datum); and SMU-438 (1386 ± 68 B.P.) and SMU-446 (1455 ± 59 B.P.) (respectively, 0.53 m and 0.38 m below datum). The reversals in ages of each of these assays are within two standard deviations and could easily be accounted for by any statistical errors in counting. With respect to the last set of reversed dates, a third date, SMU-447 (1581 ± 69 B.P.), is from the same datum depth and unit as SMU-438 but is on a sample of carbonized nut hulls rather than charcoal; I assume that SMU-447 is the more reliable of the two and also note that it is stratigraphically consistent with the superior date, SMU-446. Anomalies such as the unconformity between Strata 1 and 2 (Ahler 1976:136) and basal erosion of Stratum 4 on the west terrace are also illuminated by the radiocarbon dates. SMU-510 (3359 ± 68 B.P.) and SMU-524 (3427 ± 49 B.P.) bracket a Late Archaic burial from the base of Stratum 4, and are averaged (weighted, see Long and Rippeteau 1974) with a third basal Stratum 4 date of 3530 ± 84 B.P. (SMU-451) for an age of 3439 ± 36 B.P., which is a reasonable estimate of the age of two other Late Archaic burials (Bass and Rhule 1976). Assays that postdate 1000 B.P. are from just beneath the ground surface and do not necessarily relate to site archaeology.

The radiocarbon dating of the four strata include bracketing dates for Strata 1 to 3 and close interval dates for three separate Stratum 4 excavations. The Stratum 4 dates will be summarized later. The spans in radiocarbon years of each stratum include: Stratum 1, 10,500 (+) - 7500 B.P.; Stratum 2, 7500 B.P. - 5100 B.P.; Stratum 3, 5100 B.P.

TABLE 4.1

Rodgers Shelter Radiocarbon Dates

Laboratory Number*	5568 B.P. Half-life	Provenience	Datum Depth (m)
GAK-1170	8100±140	250NW110	3.05
GAK-1171	7010±160	250NW115	3.20
M-2332	5100±400	260NW70	1.37
M-2281	5200±200	260NW70	1.37
ISGS-35	6300±590	265NW95	1.77
A-868A	8100±300	240NW110	3.81
M-1900	8030±300	240NW105	4.52
ISGS-48	10,530±650	225NW95	8.53
M-2333	10,200±330	225NW95	8.98
A-867	430±100		
GAK-1172	7490±170	245NW110	3.44
SMU-438	1386±68	265NW110	0.53
SMU-439	2072±68	265NW110	0.69
SMU-446	1455±59	265NW110	0.38
SMU-447	1581±69	265NW110	0.53
SMU-448	2523±62	265NW110	0.84
SMU-451	3530±84	243NW75	1.43
SMU-454	2349±79	243NW75	1.20
SMU-455	1910±100	220NW405	2.28
SMU-456	195±59	220NW405	2.05
SMU-459	5130±163	220NW405	3.66
SMU-461	7957±133	220NW405	4.57
SMU-465	2617±141	220NW405	2.44
SMU-466	533±66	243NW75	1.13
SMU-467	196±66	220NW405	1.98
SMU-474	1063±98	220NW405	2.21
SMU-478	2247±73	243NW75	1.28
SMU-488	3152±63	243NW75	1.35
SMU-502	7167±164	265NW115	1.90
SMU-507	7261±292	265NW115	2.06
SMU-510	3359±68	265NW115	1.14
SMU-524	3427±49	265NW115	1.14

* All SMU dates are from 1974, 1976 excavations; all other dates are from the 1960's excavations.

- 3500 B.P.; Stratum 4, 3500 B.P. - 200 B.P. I should note that the time span of Stratum 2 differs from previous estimates 7500 B.P. - 6300 B.P. (Ahler 1976:137), reflecting the new dates from the 1976 excavation. Age assessments for Strata 3 and 4 are new also. Specific radiocarbon dates are cited in the following stratigraphic summary.

TABLE 4.2
Sedimentation Rates

Stratum	Radiocarbon Interval	Annual Accumulation	Source	Component
1	11,000-8100 B.P.	.189 cm	overbank alluvium	Dalton to Early Archaic
	8100-7500 B.P.	.166 cm	overbank alluvium	Early Archaic
2	7500-5100 B.P.	.065 cm	overbank alluvium, colluvium	Middle Archaic
3	5100-3500 B.P.	.062 cm	alluvial fan deposit overbank alluvium	cultural hiatus
4	3500-2350 B.P.	.018 cm	colluvium, alluvium	Late Archaic
	2350-500 B.P.	.015 cm	colluvium, alluvium	Late Archaic-Woodland

STRATIGRAPHY

At the shelter Terrace-1b abuts against a south-facing bluff on the north bank of the Pomme de Terre River and rests on bedrock that pitches off steeply (30°) in a series of rounded steps from the bluff toward the stream. Bedrock is about 2.7 m below the surface at the bluff-wall, is relatively shallow beneath the overhang but 20 m from the bluff bedrock lays at 9 m below the surface. Stream action probably scoured the bedrock in front of the bluff after abandonment of Terrace-1a, which Haynes (1976:57) suggests dates about 13,000 years ago. Rodgers alluvium began forming sometime prior to 10,500 B.P. and ultimately resulted in the complex stratigraphy now present at the site.

Figure 4.1 depicts the major stratigraphic units along the main (100 West line) profile, as now understood. The eleven (lettered) sedimentary units are according to Ahler (1976:131); and the stratigraphic contact between Strata 1 and 2 is redrawn, as discussed below.

Stratum 1, a compound unit of approximately 7 m thickness, formed between (probably) 11,000 and 7500 B.P. and is composed of six depositional units, with a seventh unit (B^3) being a possibility. Units A^1 , A^2 , B^1 , B^2 , and B^3 comprise the basal deposits; Unit B^1 is represented also beneath the overhang. Unit A^1 consists of lateral accretions of alluvium including scattered patinated chert gravel from the Pomme de Terre deposited directly above bedrock prior to 10,500 B.P. Cultural

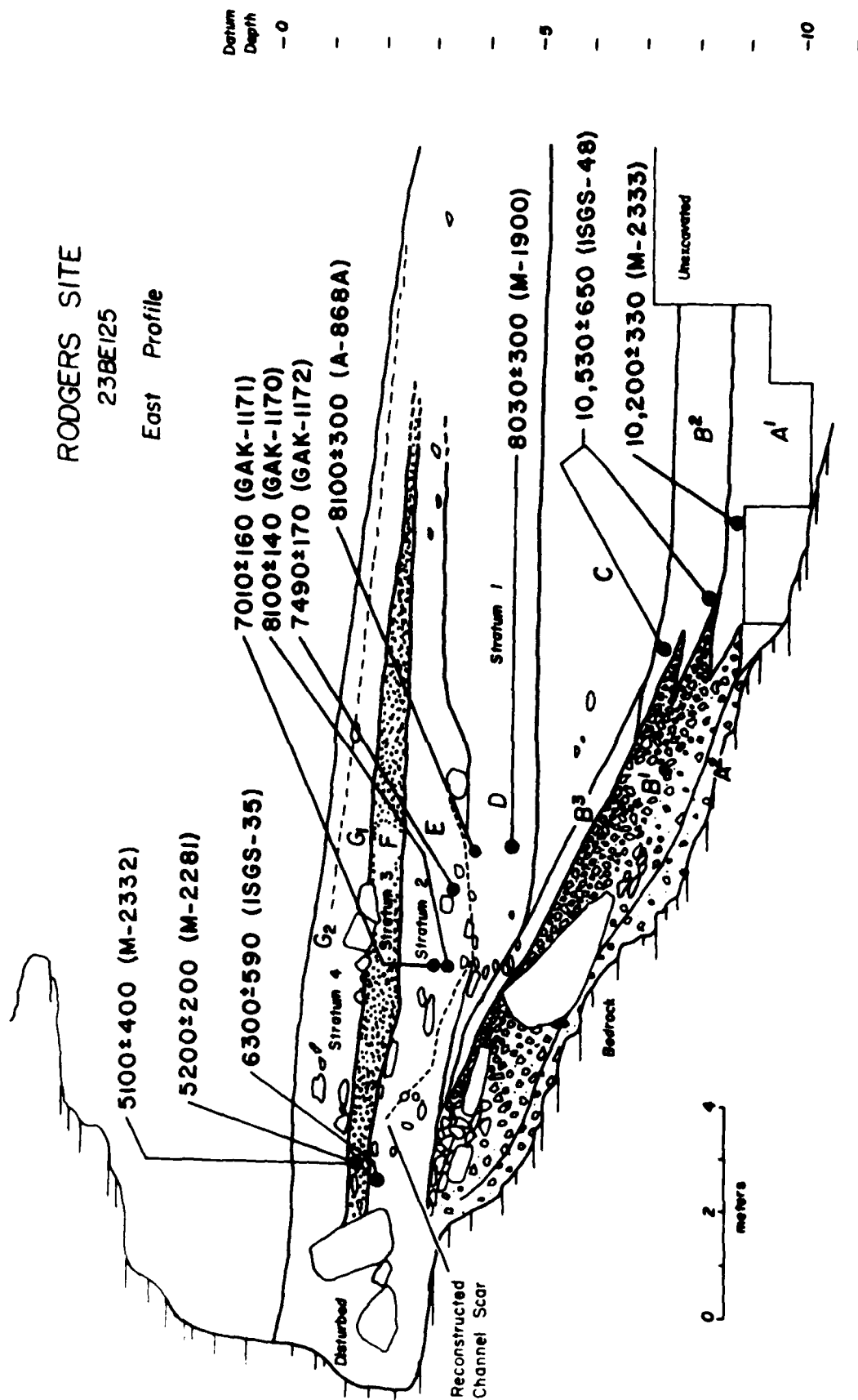


Figure 4.1. Stratigraphic units and selected dates (adapted from Ahler 1976).

materials from this layer are few and are undiagnostic. Immediately above A¹ is B², a second alluvial unit having a high clayey silt content, believed to be the product of overbank alluviation or vertical accretion from a more distant Pomme de Terre channel with a suggested date of deposition between 10,500 and 10,000 B.P. Units A², B¹ and B³ represent subdivisions of a talus of dolomite cobble derived by frost and gravity from the bluff that formed on the slope of the southward facing bedrock. Talus formation began prior to 10,500 B.P. and interbedding of talus cobble and alluvium indicates that Units B¹ and B² are contemporaneous. Based on a single sample, Unit B³ is described by Ahler (1976:134) as hypothetical but indicating a possible accumulation of eolian silt onto the talus surface. Cultural material from the talus and adjacent alluvium is identified as Dalton and is relatively prolific.

During deposition of these sediments, frost weathering of the bluff was particularly severe. Large angular blocks of dolomite were detached from the bluff and tumbled down the bedrock escarpment, almost immediately followed by deposition of the smaller, angular pieces of dolomite cobble that comprise the 1.5 m thick talus. Beneath the overhang the talus surface (Unit B¹) undulates and appears warped by frost action. McMillan (1976:223) estimates that this major thermoclastic activity ceased by about 9500 B.P.

Unit C is above the talus and the alluvium of Unit B² and is a light yellowish-brown clayey silt of alluvial origin and 2.4 m thickness. This unit is punctuated by sorted alluvial fan gravels, occurring as lenses gently dipping to the south and west. This unit represents a maximum in Terrace-1b aggradation. Ahler (1976:135) posits Unit C formed from 10,100 to 8800 B.P., but a later terminal date of 8100 B.P. is favored here because of a re-examination of radiocarbon dates. Ahler (1976:135) infers seasonally high precipitation rates from the high aggradation rate, and stable hillslope vegetation. The latter seems somewhat anomalous, given the lenses of hillslope-derived gravels. A more likely hypothesis is that Unit C records a progressive deterioration of hillslope vegetation, resultant higher effective runoff and hillslope erosion. Little cultural debris is present other than sporadic Dalton material at its base.

The uppermost subdivision of Stratum 1, Unit D, intergrades imperceptibly from Unit C and inclines northerly to the bluff. It has been possible to partially reconstruct the surface at about 8100 B.P. by plotting the provenience of fragments from a single bifacially chipped artifact, Biface 57. Beneath the overhang a flake from this artifact is found at a depth below datum of 9.4 - 9.7 ft. (2.87-2.96 m), in what was previously thought of as lower-middle Stratum 2 shelter deposits. Five feet south, other flake fragments occur at depths below datum of 10.0 - 11.5 ft. (3.05-3.51 m) in basal Stratum 2 and upper Stratum 1 main excavation units. Beyond this point there is a general leveling off of the depths below datum of Biface 57 fragments to between 12.0 and 12.5 ft. (3.66-3.81 m) over a distance of 35 ft. (10.67 m), corresponding to the base of an extensive gravel lens dated 8100±300 B.P. (A-868A). As reconstructed, this surface has a vertical relief of roughly 95 cm, with a fairly abrupt change in slope near the overhang. Overbank alluviation continued to add to Unit D until about 7500 B.P., when the terrace was down cut by a channel of the Pomme de Terre.

Ahler (1976:136) interprets Unit D's high clay content to represent alluvial deposition from a low energy (i.e., low velocity) stream environment. But this unit has a prismatic structure with thick, organic clay skins and its clay content may in part be pedogenic. The textural data from the west terrace, discussed later, is supportive also of this idea. During Unit D's formation, Rodgers was frequented by Early Archaic peoples.

McMillan (1971:81) and Ahler (1976:131) offer differing illustrations of the deflation of the upper boundary of Unit D, with McMillan favoring a single shallow basin-shaped depression and Ahler portraying two more deeply depressed basins. The original field profiles are not specific on this erosional unconformity and allow for the considerable range in opinion. Nonetheless, this unconformity was recognized in the field. Ahler (1976:132-133) attributes lateral differences in phosphorous to it and suggests that material along this contact "represents a mixture of material from the two units (Units D and C), rather than pure Stratum 2 materials, regardless of how well defined this contact may have appeared in the field." No single approach to delineate this unconformity has proved successful, although radiocarbon dating suggests formation between 8000 B.P. and 7500 B.P.

Plotting matched, or mended, bifacial fragment proveniences has allowed for a final charting of this unconformity (Fig. 4.2). As reconstructed, a deep, steep-sided basin oriented northeast bisects the excavation block, with a maximum depth of roughly 1.75 m. The reconstructed profile (B-B'; Fig. 4.2) for this basin on the 100W line correlates with large cobbles and small boulders observed on this profile, as recorded in Figure 4.1. These large rocks appear to represent a lag deposit left on the bottom of the channel. A similar erosional unconformity is apparent on the west terrace, though with an estimated depth of roughly 1 m. This channel (or channels) seemingly reflects lateral cutting across the Pomme de Terre floodplain.

Interstratigraphic mixing is documented for ten cases of a total of fifty-two mended fragmentary bifaces from correlative levels adjacent to this erosional unconformity separating Units D and E (Tables 4.3; 10.36). Thus, while mixing occurred, it probably is of insufficient magnitude to dramatically affect cultural interpretation of these two units.

Confusion has occurred, however, in the correlation of shelter and main excavation levels on either side of this erosional contact. It is now clear that the shelter was a primary locus of intense cultural activity during Unit D times, comparable and in some respects exceeding usage during Unit E, or Stratum 2. But it is not surprising that the erosional contact beneath the overhang was not recorded in the field because Unit D shelter deposits are imbued with characteristic physical properties common to Unit E in the adjacent main excavation, probably a product of intense cultural activity in these two areas. Accurate correlation of these units is possible now but is at variance with McMillan's (1976:213) earlier summary.

Unconformably overlying Unit D is Unit E, the equivalent of Stratum 2, diagnostically a very dark grayish brown clayey silt interspersed with fall rock and dolomite cobble. Ahler (1976:136-137) infers from the high incidence of frost-derived dolomite cobble that vegetation and soil cover of the hillside north of the site radically differed from

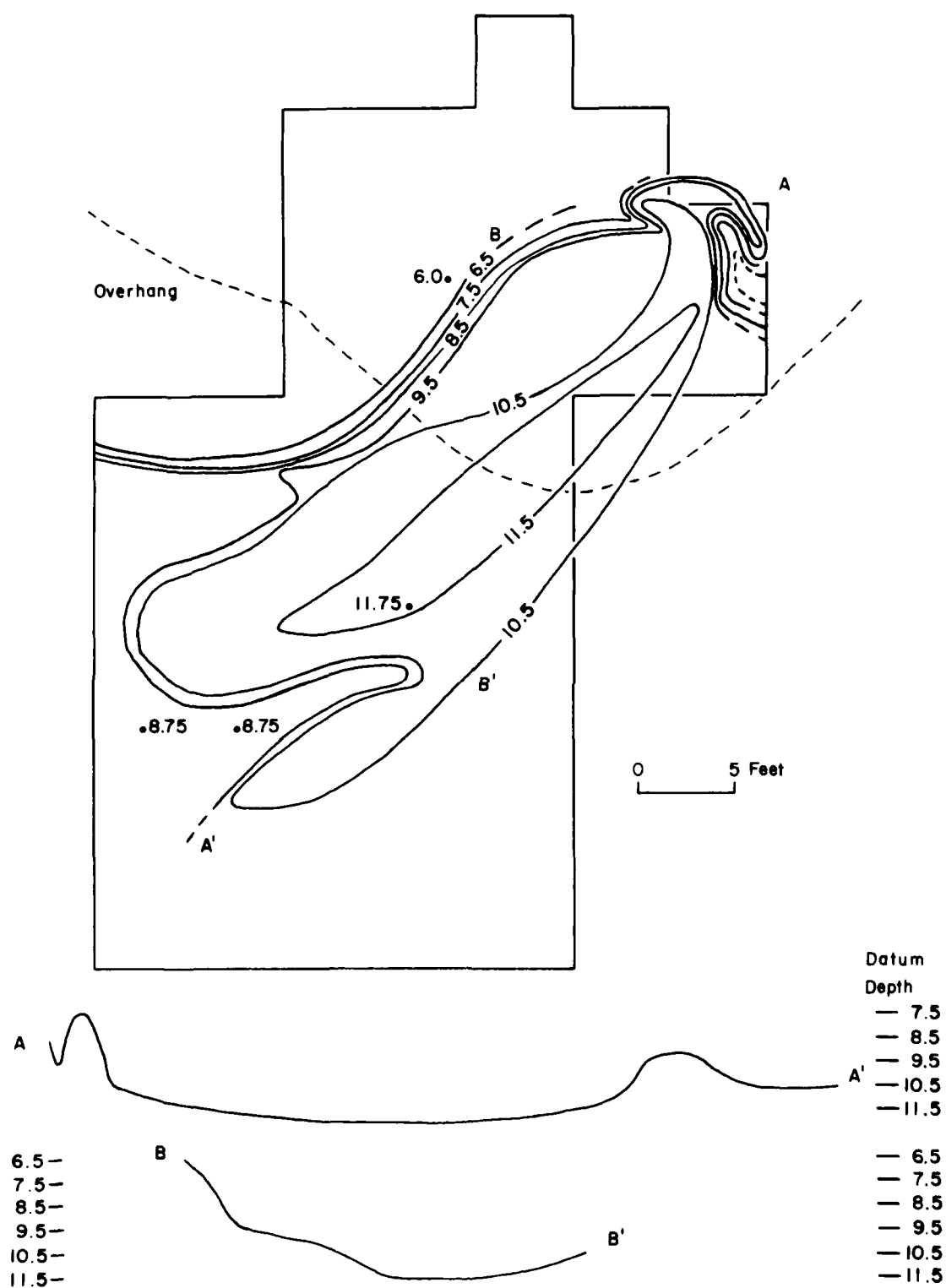


Figure 4.2. Contour map and profiles of reconstructed erosional unconformity, ca. 7500 B.P., for main excavation area, developed from matched fragments of 29 bifaces.

TABLE 4.3
Summary of Mended Biface Fragments

Specimen Number	Catalogue Number	Correlative Level	Stratum	Find Type*	Provenience	Datum Depth	Fracture Type	Techno-Functional Class
01	695 9916	11 --	2 -	2 -	230.0NW110.0 -----	8.60	4 4	5 5
02+	2641 2475	13 16	2 2	1 1	243.2NW114.3 240.0NW115.0	9.50 10.70	6 6	3 3
03	697 ---	12	2	2	230.0NW110.0	9.10	4 4	4 4
04	1792 2666	11* 12	2 2	1 2	263.2NW101.9 250.0NW105.0	6.20 8.25	5 5	8 8
05+	2760 3181	15 15	2 2	2 2	240.0NW110.0 245.0NW105.0	11.00 11.00	3 4	4 7
06+	3217 5730	15 17*	2	2 1	240.0NW105.0 361.5NW98.2	10.75 9.61	2 2	8 8
07+	7670 9953	19* 19*		1 1	258.2NW89.0 263.1NW88.8	10.60 10.95	2 2	8 8
08+	2432 2797	12 16	2 2	2 2	250.0NW110.0 240.0NW110.0	8.5 11.5	5 5	8 8
09+	5810 7985	18* 18*		2 1	255.0NW90.0 265.5NW92.6	10.75 9.40	9 2	8 8
10+	1861 3220	15 16		1 2	254.0NW103.0 245.0NW105.0	10.40 11.25	2 2	8 8

+ Data, Figure 4.2.

* 1 = from .5 foot thick excavation level of grid unit

TABLE 4.3 (continued).

Specimen Number	Catalogue Number	Correlative Level	Stratum	Find Type*	Provenience	Datum Depth	Fracture Type	Techno- Functional Class
11+	1765	16	2	2	240.ONW100.0	11.65	2,9	8
	1839	14	2	2	250.ONW100.0	9.25	2	8
12+	7780	18*		1	266.4NW90.6	9.00	3	8
	8839	15*		1	262.NW85.3	8.79	3	8
13	2371	11	2	2	250.ONW110.0	8.00	9	16
	2419	14	2	2	240.ONW115.0	9.75	2	16
14+	8234	12*	2	2	260.ONW85.0	7.50	5	17
	2952	11	2	2	245.ONW105.0	8.50	5	2
	5629	19*	1	1	255.5NW95.5	11.20	5	2
15+	1615	12	2	2	235.ONW110.0	8.75	2	8
	2726	13	2	2	250.ONW105.0	8.75	2	8
	8228	19*	1	1	265.ONW90.7	10.50	2	8
16	1428	13	2	2	235.ONW100.0	8.95	3	8
	3825	12	2	1	247.1NW120.0	8.50	3	8
17	2952	11	2	2	245.ONW105.0	8.50	4	8
	2018	15*	2	2	255.ONW100.0	9.40	2	8
18	3244	14	2	1	239.4NW107.0	9.70	6	7
	2364	14	2	1	241.8NW118.6	9.50	6	7
19	2964	12	2	1	245.3NW109.6	8.76	2	8
	2622	13	2	2	240.ONW110.0	9.25	2	8
20+	2931	16	2	1	246.9NW111.6	10.60	4	5
	2951	15	2	2	245.ONW110.0	10.25	2	7
21+	1795	11*	2	1	260.9NW101.5	6.00	4	8
	5734	17*	1	1	256.6NW94.6	10.46	4	8

TABLE 4.3 (continued).

Specimen Number	Catalogue Number	Correlative Level	Stratum	Find Type*	Provenience	Datum Depth	Fracture Type	Techno- Functional Class
22	4601 8065	-- 11*	2	2	260.0NW85.0	6.75	4	8
23	5993 7552	13* 14*	1 1	2 1	255.0NW85.0 263.4NW93.9	7.75 8.50	4 4	8 8
24	5833 5834 5694	7WT 7WT 8WT	2 2 2	1 1 1	222.5NW383.4 223.4NW382.7 221.1NW380.6	10.54 10.90 11.05	5 5 5	8 8 8
25+	1451 2678	12 15	2 2	2 1	235.0NW115.0 252.4NW105.2	8.75 9.50	5 5	8 8
26+	2962 3017	16 13	2 2	1 1	245.0NW100.4 249.5NW109.6	11.19 9.15	5 5	8 8
27	1711 3092	11 13	2 2	2 2	235.0NW100.0 240.0NW105.0	8.20 9.50	4 4	2 6
28	8234 6994	12* 11*	2 2	2 2	260.0NW85.0 260.0NW90.0	7.50 7.00	5 5	8 8
29+	680 2458	15 16	2 2	2 2	230.0NW110.0 235.0NW100.0	10.60 11.20	1 1	8 8
30	3293 587	12 11	2 2	1 1	234.3NW108.5 230.2NW107.6	8.60 ----	6 6	5 7
31	3754 2479	14 14	2 2	1 2	245.7NW100.0 245.0NW110.0	9.30 9.30	5 5	2 2
32	1780 3029	11 11	2 2	2 2	251.1NW102.5 240.0NW105.0	7.30 8.50	5 5	3 7

TABLE 4.3 (continued).

Specimen Number	Catalogue Number	Correlative Level	Stratum	Find Type*	Provenience	Datum Depth	Fracture Type	Techno- Functional Class
33+	8476	19*	1	1	259.8NW94.5	11.30	6	17
	1651	15	2	2	235.0NW110.0	10.50	6	17
34+	3159	15	2	1	240.7NW108.7	10.50	5	17
	1439	15	2	2	235.0NW115.0	10.50	5	17
35+	1765	16	2	2	240.0NW100.0	11.90	6	3
	3188	16	2	1	246.3NW105.0	11.50	6	3
36+	1615	12	2	2	235.0NW110.0	9.00	6	7
	3198	15	2	1	244.8NW109.3	10.80	3	3
37+	2772	15	2	1	250.8NW109.8	9.80	5	3
	2492	16	2	2	240.0NW115.0	11.00	5	7
38+	1513	13	2	2	240.0NW100.0	9.40	6	3
	9971	17*	2	1	263.7NW89.5	9.70	6	7
39+	3088	14	2	2	245.0NW105.0	10.00	3	14
	1569	15	2	2	240.0NW100.0	10.90	3	14
40	3064	13	2	2	245.0NW105.0	9.50	6	17
	1466	14	2	2	235.0NW115.0	10.00	6	17
	2589	12	2	1	251.8NW116.3	8.30	6	17
41	1442	11	2	2	235.0NW115.0	8.50	3	7
	2471	13	2	1	250.0NW116.3	9.70	3	5
42+	667	14	2	1	231.8NW113.3	10.25	6	3
	8065	11*	2	2	260.0NW85.0	7.00	6	7
43	2345	13	2	1	244.9NW115.8	9.00	5	6
	2385	14	2	1	241.4NW119.0	9.70	5	6

TABLE 4.3 (continued).

Specimen Number	Catalogue Number	Correlative Level	Stratum	Find Type*	Provenience	Datum Depth	Fracture Type	Techno- Functional Class
44+	1674	17	1	2	235.ONW110.0	11.30	4	3
	2520	15	2	1	245.2NW117.9	10.37	4	7
45+	3119	14	2	2	240.ONW105.0	10.00	4	7
	3151	14	2	2	240.ONW105.0	10.50	4	7
	680	15	2	2	230.ONW110.0	10.60	4	7
46+	1686	16	2	1	243.8NW103.7	11.70	3	2
	2798	15	2	2	250.ONW105.0	9.70	3	6
47	8067	19*	2	2	265.ONW90.0	10.00	5	7
	5603	15*	2	1	263.3NW96.0	8.90	5	7
48	6976	11*	2	1	260.7NW91.7	6.60	4	8
	8226	12*	2	1	260.ONW88.5	7.25	4	8
49	697	12	2	2	230.ONW110.0	8.65	5	8
	1466	14	2	2	235.ONW115.0	9.75	5	8
50	1874	15	2	2	250.ONW100.0	10.40	5	7
	3622	17	1	2	250.ONW105.0	10.90	5	7
51	3702	19	1	1	240.9NW108.3	12.50	6	3
	3703	19	1	1	242.1NW109.4	12.50	6	3
52	2944	27	1	1	228.4NW105.3	16.00	2	5
	4308	27	1	1	228.ONW107.7	16.30	2	7
53	3295	15	2	1	236.3NW107.0	10.60	8	16
	3303	15	2	2	235.ONW105.0	10.80	8	16
	7727	17*	1	1	265.9NW91.9	8.70	5	16
54	8855	20*	1	1	257.3NW87.4	11.30	3	16
	8591	20*	1	1	258.3NW85.7	11.00	3	16

TABLE 4.3 (continued).

Specimen Number	Catalogue Number	Correlative Level	Stratum	Find Type*	Provenience	Datum Depth	Fracture Type	Techno- Functional Class
55	3631	18	1	1	339.8NW103.3	11.60	4	14
	3459	18	1	2	235.0NW105.0	12.00	2	14
56	3746	19	1	1	244.3NW113.3	12.10	6	16
	3760	19	1	2	235.0NW110.0	12.50	6	16
57	3704	19	1	1	240.6NW108.8	12.50	3	3
	3759	19	1	2	230.0NW110.0	12.50	2	7
	4633	19	1	1	228.0NW119.7	12.50	2	7
	3759	19	1	2	230.0NW110.0	12.50	6	7
Attached								
Flake								
58	2063	16*	1	2	255.0NW100.0	9.65	-	--
59	2855	16	2	2	250.0NW105.0	10.25	-	--
	3220	16	2	2	245.0NW105.0	11.25	-	--
	3636	17	1	2	250.0NW105.0	11.25	-	--
	3680	18	1	2	245.0NW105.0	11.75	-	--
60	2516	14	2	1	253.5NW110.4	9.30	6	7
	3491	17	1	1	244.2NW116.4	11.30	6	7
61	683	16	2	1	234.8NW112.9	10.50	2	3
	5207	M	2				3	3
62	1650	15	2	2	245.0NW100.0	11.10	5	7
	2648	14	2	1	244.2NW113.7	9.80	5	7
63	5417	11*	2	2	255.0NW90.0	7.50	5	6
	5417	11*	2	2	255.0NW90.0	7.50	5	6
	1650	15	2	2	245.0NW100.0	11.10	5	6

TABLE 4.3 (continued).

Specimen Number	Catalogue Number	Correlative Level	Stratum	Find Type*	Provenience	Datum Depth	Fracture Type	Techno- Functional Class
62	1391	11	2	2	220.ONW110.0	12.40	6	16
	1710	14	2	2	230.ONW115.0	9.80	6	6
63	9955	20*	1	1	261.5NW85.7	11.00	3	8
	9129	21*	1	1	259.2NW85.5	11.70	4	8
64	2841	16	2	2	250.ONW105.0	10.50	9	7
	2875	12	2	2	245.ONW110.0	9.30	2	6
65	5490	14*	1	2	260.ONW95.0	8.25	4	7
	5434	12*	2	1	262.5NW95.5	7.20	4	7
66	2430	13	2	1	252.1NW113.4	9.00	3	3
	2951	15	2	2	245.ONW110.0	10.80	4	7
67	1766	18	1	2	235.ONW110.0	11.50	6	8
	3435	18	1	1	234.8NW109.1	11.90	4	8
	3447	18	1	2	230.ONW105.0	11.75	4	8
	3760	19	1	2	235.ONW110.0	12.15	6	8
68	7	03	4	2	240.ONW95.0	4.40	6	4
	2835	02	4	1	234.8NW121.7	5.40	6	4
69	41A	02	4	1	250.1NW98.9	2.30	5	20
	----						5	20
70	5322	M	4				2	8
	2312	02*	4	2			2	8
71	15	04*	4	2	255.ONW95.0	2.80	3	20
	32	05*	4	2	265.ONW95.0	3.00	3	20
72	258	04	4	2	235.ONW115.0	5.80	6	2
	347	03	4	2	245.ONW115.0	3.60	6	2

TABLE 4.3 (concluded).

Specimen Number	Catalogue Number	Correlative Level	Stratum	Find Type*	Provenience	Datum Depth	Fracture Type	Techno-Functional Class
73	181 442	01 04	4 4	2 2	225.ONW100.0 235.ONW105.0	5.00 5.60	4 2	7 7
74	373 15	04 04*	4 4	1 2	242.9NW118.2 255.ONW95.0	5.20 2.50	5 5	2 2
75	475 9915	05 --	4 -		250.ONW105.0	3.80	5 5	8 8
76	505 3185	01 --	4 4	2 2	230.ONW105.0	4.25	5 5	8 8
77	518 264	02 03	4 4	1 2	226.ONW106.0 230.ONW100.0	0.10 5.50	4 6	2 2
78	289 447	01 02	4 4	2 2	215.ONW100.0 220.ONW100.0	6.20 6.30	2 2	4 4
79	354 428	04 01+	4 4	1 2	238.2NW111.2 220.ONW100.0	5.30 5.25	3 3	8 8
80	515 530	04 05	4 4	2 1	230.ONW105.0 234.9NW108.8	5.75 6.10	3 3	8 8
81	45 578	05 04	4 4	2 2	250.ONW95.0 230.ONW110.0	3.75 5.65	3 3	8 8
82	4300 4408	39 39	1 1	1 1	249.8NW117.3 248.5NW113.7	15.60 16.40	4 2	14 14
83	1256 1258	03 03	4 4	2 1	245.ONW105.0 247.2NW109.3	3.60 3.70	8 8	2 2
84	4753 4771	39 39	1 1	1 2	224.4NW101.5 225.ONW95.0	23.66 23.25	2 9	8 8

prevailing conditions during Stratum 1, that bedrock was widely exposed to erosion, and from an apparent reduction in aggradation by the Pomme de Terre River that a lower volume of water moved through the valley; concluding that: "considering all evidence, we can hypothesize this to have been a period of decreased precipitation." He further notes that peaks in available phosphorous indicate some soil formation, and Haynes (1977:27-28) describes this unit as in part correlated with a buried paleosol. Structurally, the sediments are angular blocky with organic clay skins, hard when dry; high in cultural debris. The lower and upper boundaries are abrupt but, as Unit E thins laterally, becoming less distinct on the terrace at greater distances from the bluff and shelter area. Again, this appears to be a function of occupational intensity. Similar strata are recognized in Rodgers alluvium at other lower Pomme de Terre sites where intense, short-term human occupation occurred. Maximum thickness of Unit E is 1.8 m, recorded in the main excavation, while on the west terrace thickness varies from roughly 30 to 50 cm. Culturally, Stratum 2 is described as a Middle Archaic (Ahler and McMillan 1976) depositional unit, though there are major stylistic and technological continuities with the preceding material culture of Unit D.

Basal dates for Unit E are roughly 7500 B.P. from the main excavation and a single date of 6300 ± 590 B.P. (ISGS-35) is from the upper boundary beneath the overhang. A date of 5130 ± 163 B.P. (SMU-459) from the much thinner west terrace Stratum 2 deposit does not seem questionable, and indicates Stratum 3 began to form about 1170 years later than had been previously believed. Thus suggested dates for Unit E formation are from 7500 to 5100 B.P.

Unit F, or Stratum 3, an interlayered sequence of coarse alluvial fan deposits which emanated from the two hillside hollows on either side of the shelter, conformably overlies Unit E. Maximum thickness is near the hillside hollows, and in the nearby main excavation Unit F has the appearance of a homogeneous gravel sheet of about 1 m thickness. Exposures at a greater distance, particularly those from the 1976 west terrace excavations, show clearly an interlayering of sorted gravels and alluvium, with a minimum of three discrete episodes of alluvial fan deposition. Colluvial deposition of large dolomite cobble, derived by frost-and-gravity along the bluff, apparently increased also during Unit F, as observed in west terrace excavations (Fig. 4.3). Ahler (1976:137) underscores that Unit F "represents both a cessation in overbank alluviation by the Pomme de Terre River and a maximum in local hillslope erosion." As described here, however, river aggradation continued to be the controlling factor even though hillslope erosion reached a maximum. Stated differently, Stratum 3, or Unit F, represents a floodplain morphology with localized lateral accretions of coarse alluvial fan deposits emanating from hillside hollows. Ahler's (1976:137) hypothesis of "minimum vegetation cover on the hillside above the site, and minimal precipitation, coming perhaps in the form of intense seasonal thunderstorms" as prevailing environmental and climatic conditions during Unit F deserves serious consideration, and to a degree is supported by analyses reported later. Evidence of habitation is restricted to a thin scatter of lithic artifacts associated with a

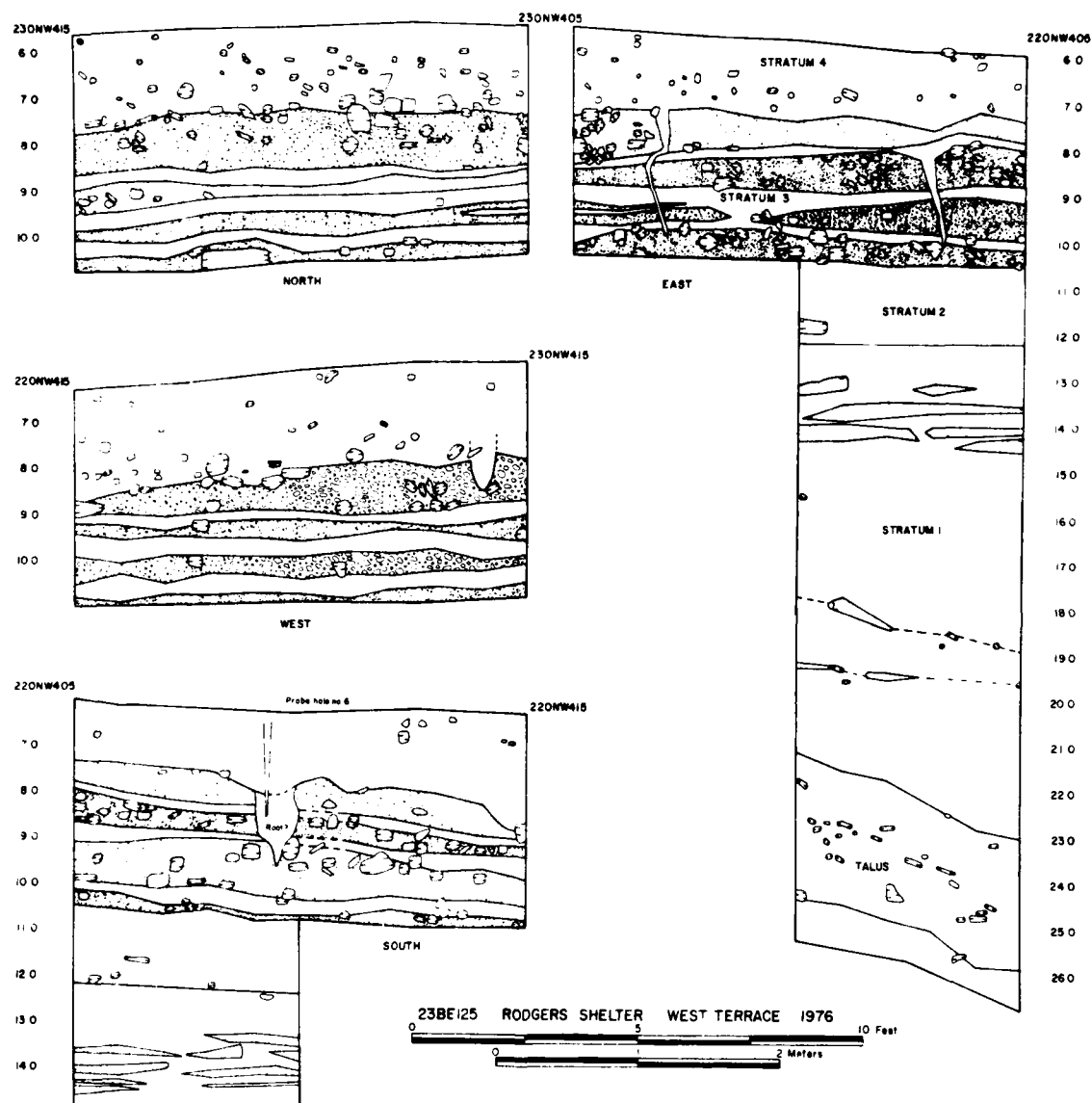


Figure 4.3. Schematic profiles of stratigraphic column, West Terrace, 1976. Datum depths are in feet. Gastropod column was removed from the southeast corner.

mussel shell filled pit, excavated into Stratum 3 gravels beneath the overhang, with reported dates (Crane and Griffin 1972) of 5100 ± 400 B.P. (M-2332) and 5200 ± 200 B.P. (M-2281). Unit F is significant culturally in that it represents an abandonment of Rodgers Shelter, and probably other toe-of-slope sites, during the period from 5100 to about 3600 B.P. The Rodgers cultural hiatus of 1500 years largely may have come about because the massive deposits of coarse gravels made the floodplain at the base of hillslopes unsuitable for habitation, though the impact of decreased precipitation, arid or severe drought conditions cannot be overlooked. Phillips, an artesian spring and perennial source of potable water near the center of the Pomme de Terre valley upstream from Rodgers Shelter, was repeatedly inhabited during this time.

Stratum 4, a very dark gray clayey silt, is subdivided by Ahler (1976:137-138) into Units G^1 and G^2 , primarily from field observations of fall rock and cobble content from the main excavation. Unit G^1 , the lower of the two, is characterized by larger sized and greater amounts of rock debris and corresponds to the Late Archaic and Woodland habitations, ca. 3600 to 1000 B.P. The unit dips toward the two ravines on either side of the shelter and Terrace-1b appears to have been laterally incised during early Unit G^1 time. Pronounced terrace entrenchment, resulting in the two present ravines, did not occur until much later. Tree root molds extend from the base of Unit G^1 into Unit F, indicating forested conditions. And Ahler (1976:138) interprets the high concentrations of frost-derived dolomite cobble (Figs. 4.3, 4.4) to indicate reduced temperatures during the early part of Unit G^1 deposition. Ahler further assumes that hillside vegetation was denser than during Unit F, though Unit G appears to be largely derived from colluvial action along the hillslope with minor increments of overbank alluvium from the Pomme de Terre possibly being present, and that precipitation was similar to present rates.

The relatively rock-free Unit G^2 conformably overlies Unit G^1 and near-surface dates are 533 ± 66 B.P. (SMU-466) and 195 ± 59 B.P. (SMU-456). Unit G^2 exposures on the west terrace, when thoroughly dry, are a lighter gray than Unit G^1 , crack from this underlying unit that has a well developed angular blocky structure and clay skins on ped surfaces, and have a massive, or undifferentiated, structure common to the T-0 sediments. A date for T-0 alluvium (Pippens; see Haynes 1977) at Rodgers is 430 ± 100 B.P. (A-867) comparing favorably with the two dates on Unit G^2 .

Beneath the shelter, an area riddled with either recent man-made or rodent disturbance, a three unit subdivision of Stratum 4 is evident from a 1974 excavation profile drawn in 1976 (Fig. 4.5). The base of Stratum 4 is a dark gray, charcoal rich, sandy silt loam with large fragments of fall rock, concentrated cultural debris and burned earth. The lower contact with Stratum 3 (Unit F) is abrupt and there is a gradual upper transition. This unit has a porous, granular (crumb) structure; when wet, a slightly plastic but not sticky consistence. Two charcoal samples have been dated as 3427 ± 49 B.P. (SMU-524) and 3359 ± 68 B.P. (SMU-510). Diagnostic cultural items are Late Archaic. Above this is a grayish brown, sandy silt zone with a high charcoal content and a continuation of large fall rock debris. The upper contact is abrupt. The unit again has a crumb structure but, when wet, is neither plastic



Figure 4.4. Stratigraphic column excavated along 75W line (between 240N and 250N) in 1976; right: east wall, center: north wall, left: west wall. Datum depths are in feet. Gastropod column removed from west wall.

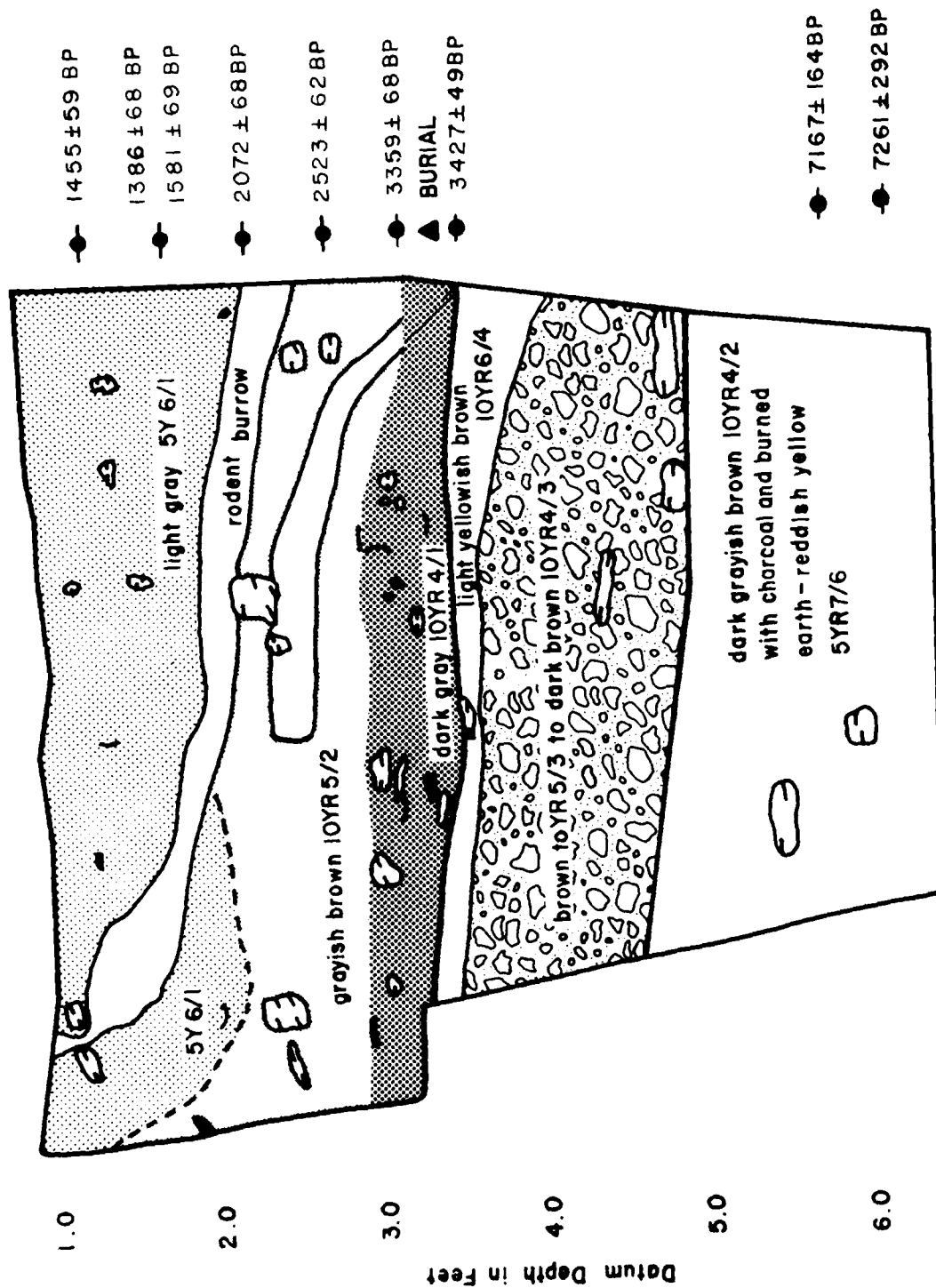


Figure 4.5. Schematic profile of 1974 excavation beneath the overhang.

nor sticky. A basal date for this unit is 2523 ± 62 B.P. (SMU-448). An upper date is 2072 ± 68 B.P. (SMU-439). Artifacts include both Late Archaic and Woodland forms. These two lower zones are subsumed within Unit G¹ in front of the overhang. The final unit is a light gray, sandy silt zone with scattered small gravels and a high charcoal content. Texture, structure and consistence are similar to that of the preceding unit, and it contains primarily Woodland or Mississippian artifacts. Dates include two from the basal portion, one on charred nuts of 1581 ± 69 B.P. (SMU-447), one on charcoal of 1386 ± 68 B.P. (SMU-438); and a near surface date of 1455 ± 59 B.P. (SMU-446).

INTRASITE CORRELATION

Excavation of this magnitude presents major problems for intrasite analysis. A prime difficulty is to devise systematic means of intrasite correlation that accurately reflects relative and/or absolute temporal order among excavation areas. For each of the four Rodgers Shelter excavation areas, McMillan (1971) devised separate correlative level summaries, related internally by superposition. He further commented that: "A disadvantage of the correlative levels was that they represented differing time spans because of varying sedimentation rates" (McMillan 1971:174). To clarify diachronic trends in the main excavation and shelter areas, McMillan (1971:174-175) further aggregated various correlative levels into eight time-stratigraphic units, assigned to more-or-less absolute temporal levels. These were later expanded to twelve *culture/time stratigraphic units*, defined as "*chronologically discrete horizons that have been assigned absolute temporal limits and, based on subsistence data and activity indicators, contain levels that display some degree of cultural homogeneity when compared with units above or below them* [original emphasis] (McMillan 1976:211)."

For certain of these units, however, the suggested correlation among shelter and main excavation areas (McMillan 1976:213) was recognized to be suspect (Ahler 1976:136) due to terrace deflation and subsequent sediment mixing. An independent program of matching broken bifacial tool fragments, discussed above, has verified this, indicating as well that the correlative levels generally are too fine for *intrastratigraphic* analysis and often are wholly arbitrary subdivisions. Varying intensity of site use and intrasite activity combined with erosion and other pedoturbational processes have skewed the vertical and horizontal distributions of cultural debris.

Culture/time stratigraphic units, suitably revised, remain the most practical method of ordering site cultural stratigraphy. For simplicity, *culture/time stratigraphic units* are referred to as *horizons* in this study. I may also note that each unit, or horizon, is an aggregate of cultural behavior of greater or lesser scale, due to the depositional history, the duration, magnitude and kinds of site activity. As a consequence, the basal Dalton horizon is represented by discrete, individual "living floors;" whereas similar floors are not identifiable for many of the superior horizons. These in a real sense constitute an amalgamation of activity for a temporal interval, and distributional configurations (Chapter 12) represent a temporal average.

Intrasite correlation has been effected by revising McMillan's twelve culture/time stratigraphic units into eleven horizons that reflect stratigraphic relationships, as now understood, and by considering the series of radiocarbon dates, including those from the 1974 and 1976 excavations. The new radiometric dates allow for the first accurate correlation of the west terrace and main excavation area and an absolute scale of the later horizons. Nonetheless, it still is not possible to accurately correlate the terrace excavations with either the main excavation area or the west terrace. Probably it never will be because there is insufficient charcoal for radiocarbon dating.

Table 4.4 summarizes intrasite correlations and represents a major advance in our ability to manipulate site data. Conventional period designations (Chapman 1975) are followed in grouping horizons.

TABLE 4.4
Revised Horizons* at Rodgers Shelter

Horizon	Temporal Span+	Cultural Affiliation	Stratum	Correlative Level		
				Shelter	Main Excavation	West Terrace
1	1000-1750	Woodland/ Mississippian	4	1, 2	1, 2	1-3
2	1750-2500	Woodland/Late Archaic	4	3-5	3, 4	4
3	2500-3600	Late Archaic	4	6-8	5, 6	4/5
4	3600-5200	Little occupation	3	9, 10	7-10	5
5	5200-6700	Middle Archaic	2	11	11-14	6-10
6	6700-7500	Middle Archaic	2	12	15, 16	11
7	7500-8100	Middle-Early Archaic	2/1	13-18	17, 18	12-13
8	8100-8600	Early Archaic	1	19	19-25	14-18
9	8600-9500	Little occupation	1	20	26-35	19
10	9500-10500	Dalton	1	21-24	36-41	20-21
11	10500-11000	Little occupation	1	25	42	22

+ radiocarbon years

* replaces culture/time stratigraphic units of McMillan 1976.

CLOSE INTERVAL DATING AND INTRASITE CORRELATION

A methodological advancement is the close interval dating of 1974 and 1976 Stratum 4 excavations. These allow for detailed statement of Horizons 1 to 3 temporal subdivisions (Table 4.5) and the accurate summary of Stratum 4 deposition rates (Table 4.2). This is important because the very slow deposition of Stratum 4 resulted in compacted, poorly segregated cultural components, which--without close interval dating--would have been impossible to competently separate. A second benefit has been that we can now correlate areas beneath the overhang, to its front in the main excavation and on the west terrace that are roughly comparable in matrix recovery but vary in site usage for a period of almost 4000 years. In Table 4.4 these correlations are presented for the 1974 and 1976 excavations only. Correlation of these units only is advisable because they alone are dated and there is the chance of lateral and vertical mixing of materials from one correlative level to another, as demonstrated by matching fragmentary bifaces from Stratum 4. Only in the basal Stratum 4 excavation units (Horizons 3B and 3C) would it be practical to apply this correlation to the 1960's shelter and main excavation units. For whatever reasons, disturbance of basal Stratum 4 units appears to be minimal in the main excavation block, notwithstanding deflation of this zone which had a major impact on Stratum 4 sediments east of this block and on the west terrace.

TABLE 4.5

Correlation of 1974, 1976 Excavations

Horizon	Subdivision	B.P. Mean Age	1974 Shelter	1976 Main Excavation	1976 West Terrace
1	A	500 or less		1-2	1-2
	B	1063±98*			3
	C	1518±52*	1-2		
2	A	1910±100	3		4
	B	2223±97*	4	3-4	
3	A	2570±128*	5		4/5
	B	3152±63	6?	5	
	C	3439±36*	7-8?	6	

* weighted average of two or more dates (cf., Long and Rippeteau 1974);
5568 half-life.

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CHAPTER 5

CHANGE IN DEPOSITIONAL ENVIRONMENTS AT RODGERS SHELTER

Marvin Kay

The sedimentary record of Rodgers Shelter reflects the geomorphology, environment and climate of its catchment basin. These can be productively thought of in terms of *effective hillslope runoff*, *river aggradation*, *deposition rates* and *soil genesis*. Of these, the first two require operational definition because they cannot be directly quantified. *Effective hillslope runoff* is a relative concept of the impact of runoff on the hillslope above the site, principally measured by the amounts of hillslope-derived rock debris from known volumes of terrace sediment from (hopefully) optimally placed stratigraphic columns. Changes in effective hillslope runoff should correlate with environment and climate mainly since the hillslope retained a constant position relative to the terrace. *River aggradation*, the vertical accretion of floodplain alluvium, can be approximated by mechanical, or textural, analysis of sediments, also a supplemental technique for documenting soil genesis. Causes of river aggradation are often complex and may well involve a combination of geomorphic, environmental and climatic variables; the effect of river aggradation at Rodgers Shelter has been the deep burial of archaeological components in a multilayered context. *Deposition rates*, the amount of sediment accumulating per unit of time, and *soil genesis*, the development of a zonal soil profile beginning at a ground surface, are primary means of assessing landscape stability through time, which obviously was affected by multiple geomorphic, environmental and climatic conditions. The problem now is to model these four variables into, I hope, a coherent scheme of environmental change, a process begun by Ahler and McMillan.

It will be valuable to assess the newly collected data and analyses of the sedimentary record of the Rodgers terrace as part of an overall discussion of Holocene environments. The next two sections describe these data, analyses and interpretations; followed by a final summary discussion. Perhaps these efforts will suggest a better methodology for both field and laboratory approaches to deep site archaeology though they had little to do with the excavation of Rodgers Shelter.

pH AND MECHANICAL ANALYSES

Most of the inferences on sedimentary deposition and environmental change that Ahler made were based on mechanical and chemical analyses of 25 main excavation area soil samples, selectively chosen from zones of major stratigraphic or depositional contrast. The chemical analyses were "largely of secondary importance (Ahler 1976:125)" to the understanding of the deposition environment and stratigraphic subdivisions and will not be further considered. Size distribution of particles larger than clay (0.002 mm) was determined by a combination of an hydrometer method for silt (0.002-0.06 mm) and wet sieving for sand and gravel (0.06 mm or larger). Relative percentages of standard textural

classes (sand, silt, clay), the mineral and rock composition of particles greater than 0.35 mm in diameter for the samples were used as input data for a R mode principal components factor analysis "in an effort to reduce the original variation in the data to a small number of patterned relationships, and to discover a small number of basic independent operating dimensions or factors responsible for the accumulation of deposits at the site" (Ahler 1976:127). Three rotated varimax (orthogonal) factors were generated, each interpreted to represent meaningful components of the depositional process. Their factor scores ("a direct measure of the influence of each of the three independently operating depositional processes at any one point in time or place in the stratigraphy" [Ahler 1976:129]) for each case (sample) were used in a second multivariate technique, hierarchical cluster analysis to gain additional information. Ahler (1976:129-130) explains: "By clustering cases or samples on the basis of similarity in factor scores, groups of samples can be found that represent depositionally distinct stratigraphic units in the site, and that represent periods of time when a relatively consistent set of depositional processes were in operation."

The same multivariate approaches are followed in this analysis and for the same reasons. However, the data are different and are not directly comparable, as explained in the following.

A hydraulic soil probe was used to remove continuous sediment columns from the ground surface to bedrock on the west terrace. The columns were generally from between the 405W and 415W grid lines spaced at irregular intervals from the bluff. Three columns (3, 4, 6) were sampled at about 0.5-foot intervals and at stratigraphic contacts for pH and mechanical analysis. Column 6 was closest to the bluff (11 m south) and was almost tangent with the south wall of the stratigraphic column (Fig. 4.3) later excavated, and was of similar depth (6.7 m). Three meters south of Column 6 was Column 4, which reached bedrock at a depth of 8.1 m, and 8 m farther south was Column 3, the deepest column (9.75 m) also reaching bedrock.

The mechanical analysis procedure used pipette, wet and dry sieving to derive standard textural classes according to the Wentworth scale (Anonymous n.d.; Table 5.1), and pH was read with a Beckman single electrode pocket pH meter. Data recorded for each sample included pH and relative percentages of sand, silt (31, 16, 8, 4, 2 microns) and clay. For convenience and to reduce redundancy, these data were selectively sampled for vertical contrasts within and between strata, resulting in a matrix of 71 cases divided among the three columns (Table 5.2). This matrix of pH and standard textural classes for 71 samples was used as input data for a R mode principal components factor analysis (PA1; Kim 1975).

Principal components defined three unrotated factors having eigenvalues greater than 1.0, accounting for 71.6 per cent of the total variance, that were orthogonally rotated into three (varimax) factors. Inspection of the factor loadings (Table 5.3) that express the relative contribution of a variable to a factor shows that each factor has high positive and high negative loadings for some of the variables and that each variable is important to one factor or another. In this respect these results are very similar to Ahler's (1976) analysis where two factors

TABLE 5.1

Fractions Separated

Pipette	Wet Sieving	By Difference	Dry Sieving
≥31μ	>62μ	31-62μ	0.125 mm
16μ			0.250 mm
8μ			0.500 mm
4μ			1.000 mm
2μ			>2.000 mm

have dichotomous variable distributions. Ahler's (1976:128-129) third factor, however, that shows an inverse relationship among the fine-grained materials (clay and silt) and coarser dolomite sands, is most closely approximated by this analysis, while the other two factors are largely incorporated in the analysis of natural rock debris, discussed in the next section.

TABLE 5.2

Principal Components Data Matrix

Sample	Sand	Relative Percentage Silt*					CLAY	pH
		31	16	8	4	2		
3-01	7	11	20	20	8	3	31	5.2
3-02	6	10	14	15	7	3	45	4.7
3-03	27	7	9	12	6	1	38	5.9
3-04	10	11	14	16	9	5	35	7.1
3-05	4	8	17	18	9	4	40	7.2
3-06	2	8	18	20	10	4	38	7.1
3-07	10	10	15	15	9	5	36	7.5
3-08	3	7	17	21	11	4	37	7.1
3-09	4	9	19	18	11	3	36	7.0
3-10	4	9	21	17	11	5	33	7.0
3-11	4	7	22	18	10	4	35	7.0
3-12	20	3	18	13	13	1	32	7.1
3-13	3	9	20	18	12	4	34	7.0
3-14	1	5	22	22	13	5	32	7.0
3-15	7	2	23	23	12	2	31	7.0
3-16	3	8	22	19	10	5	33	7.1
3-17	2	9	28	19	11	5	26	7.1
3-18	34	5	15	11	9	3	23	7.1

* silt fractions are in microns.

TABLE 5.2 (continued)

Sample	Sand	Relative Percentage					Clay	pH
		31	16	Silt* 8	4	2		
3-19	6	9	22	18	10	4	31	6.9
3-20	1	9	23	20	11	6	30	7.0
3-21	2	11	20	18	11	5	33	7.1
3-22	3	10	23	17	10	4	33	7.1
3-23	6	7	23	18	10	4	32	7.1
3-24	3	6	22	20	8	6	35	7.2
3-25	8	3	22	20	10	6	31	6.9
3-26	2	3	22	25	12	5	31	7.0
3-27	5	3	26	23	9	4	30	7.1
4-01	12	8	21	12	10	6	31	6.5
4-02	17	6	16	12	9	4	36	6.2
4-03	14	4	14	10	8	4	46	6.5
4-04	38	9	11	8	5	3	26	7.4
4-05	6	7	16	15	9	7	40	7.2
4-06	3	4	19	20	11	7	36	7.3
4-07	4	12	17	14	10	3	40	7.4
4-08	16	10	17	12	9	2	34	7.4
4-09	3	9	18	17	12	2	39	7.3
4-10	4	10	20	12	11	3	40	7.4
4-11	16	13	15	12	8	6	30	7.4
4-12	4	9	21	16	12	5	33	7.2
4-13	6	9	23	16	11	6	29	7.1
4-14	3	13	22	14	12	5	31	7.3
4-15	1	14	27	18	11	5	24	7.3
4-16	7	9	21	15	11	6	31	7.2
4-17	27	9	13	8	8	5	30	7.3
4-18	2	9	25	18	12	6	28	7.2
4-19	1	9	18	23	12	5	32	6.8
4-20	1	13	20	22	12	6	26	7.1
4-21	2	11	20	21	10	5	31	7.0
4-22	3	20	18	21	11	3	25	7.2
4-23	6	11	21	19	9	4	30	7.2
6-01	18	9	18	8	7	7	33	6.4
6-02	9	9	19	12	8	8	35	6.4
6-03	12	7	15	8	7	4	47	6.4
6-04	41	6	11	5	6	5	26	7.3
6-05	3	7	18	15	10	7	40	7.1
6-06	8	9	18	10	9	6	40	7.3
6-07	38	4	13	7	6	3	29	7.5
6-08	5	9	18	12	10	6	40	7.4
6-09	5	13	14	15	10	6	37	7.1
6-10	23	6	15	10	8	5	33	7.2
6-11	6	10	16	15	9	6	38	7.2
6-12	3	52	10	8	4	2	21	7.2
6-13	8	11	17	13	10	5	26	7.2

TABLE 5.2 (concluded)

Sample	Sand	Relative Percentage Silt*					Clay	pH
		31	16	8	4	2		
6-14	4	6	20	18	10	7	35	6.9
6-15	3	7	22	18	11	8	31	7.3
6-16	2	4	19	20	11	9	35	7.6
6-17	3	6	20	19	11	7	34	7.2
6-18	2	3	22	18	10	8	37	7.1
6-19	4	6	22	17	11	6	34	7.1
6-20	2	4	21	19	10	5	39	7.1
6-21	6	7	21	16	9	8	33	7.1

Factor 1 has high positive loadings on 16 - 4 micron silt and a high negative loading on sand, indicating that deposition of the two varied inversely. This factor is interpreted as reflecting overbank alluviation by the Pomme de Terre River, dichotomized by hillslope-derived sediments flushed onto the floodplain, and is most similar to Ahler's third factor. Factor 1 scores plotted by datum depth for each column (Figs. 5.1-5.3) show a basic pattern of predominate vertical accretion by the Pomme de Terre River (positive scores) punctuated by episodes of hillslope-washed sediments (negative scores). The affects of hillslope runoff are most pronounced nearest the bluff (Column 6; Fig. 5.1) and had less impact at greater distances from the bluff (Column 3; Fig. 5.3), and the converse is true for alluvium. A second feature is that alluvial deposition was most important in the early build up of Stratum 1, became progressively less intense toward the contact with Stratum 2 but remained important throughout the depositional history of Terrace 1b. On the other hand, hillslope runoff irregularly added coarse sediments to the middle or upper portions of Stratum 1 and to Stratum 3.

TABLE 5.3

Varimax Rotated Factor Matrix*

Variable	Factor 1	Factor 2	Factor 3
Sand	-0.89	0.16	0.04
31 Silt	-0.06	0.17	-0.84
16 Silt	0.81	0.24	0.24
8 Silt	0.90	0.03	0.07
4 Silt	0.77	0.14	0.31
2 Silt	0.17	0.14	0.61
Clay	-0.03	-0.80	0.36
pH	-0.01	0.74	0.28
Depth in m	0.60	0.61	-0.01
% Unrotated	40.10	18.50	13.00

*high loading (>0.7) and moderately loading (>0.6) variables are in *italics*.

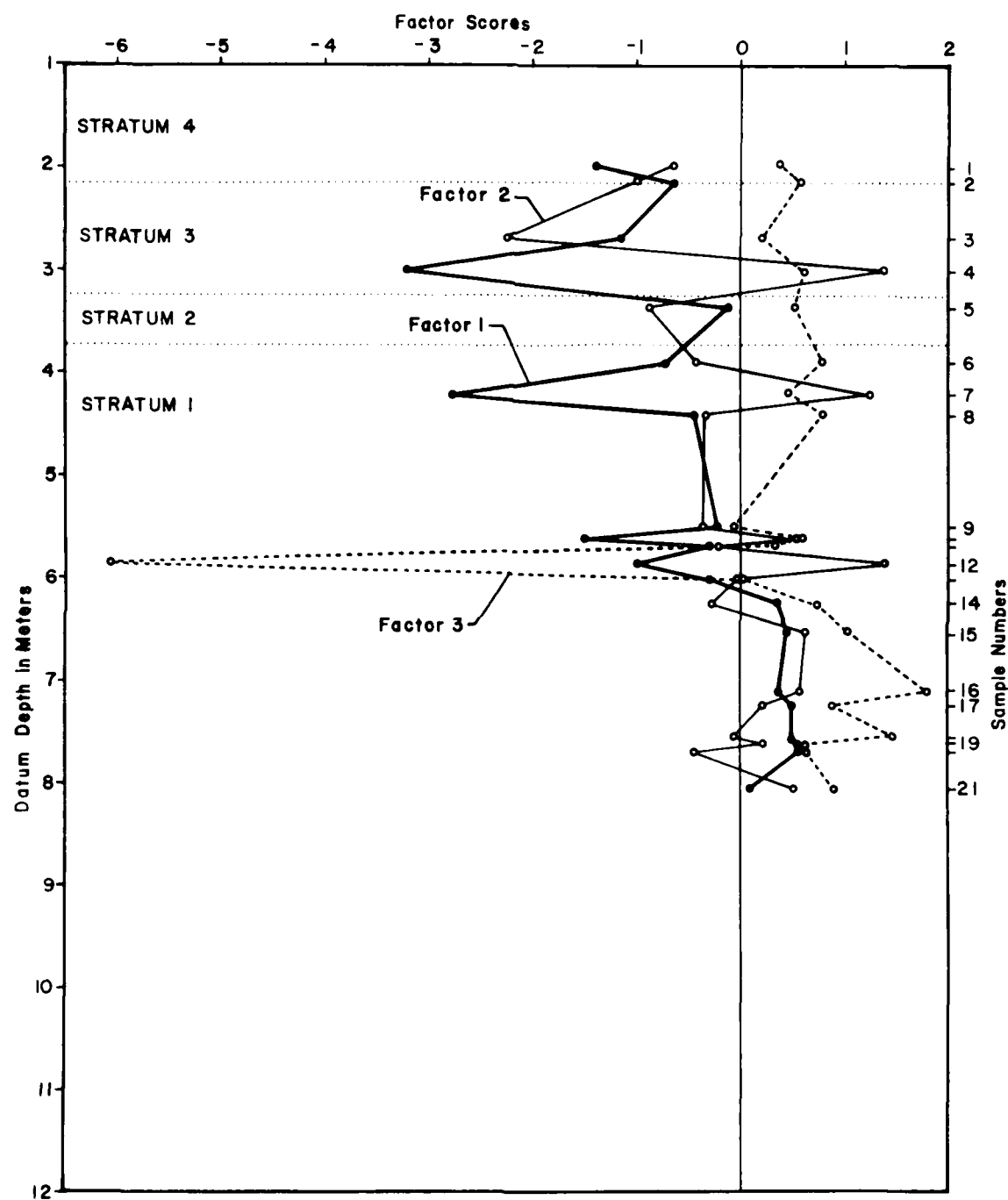


Figure 5.1. Plot of factor scores for Column 6.

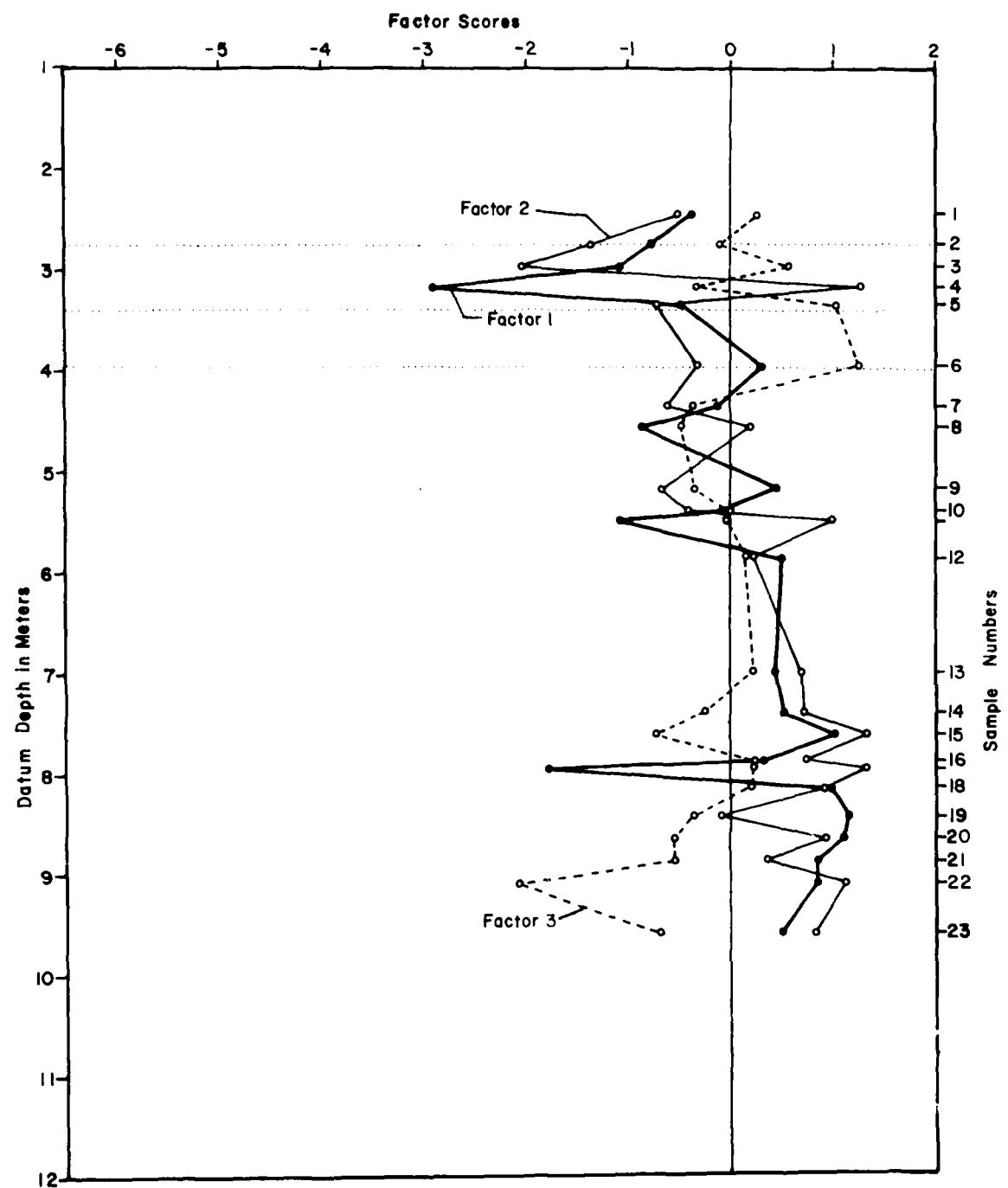


Figure 5.2. Plot of factor scores for Column 4.

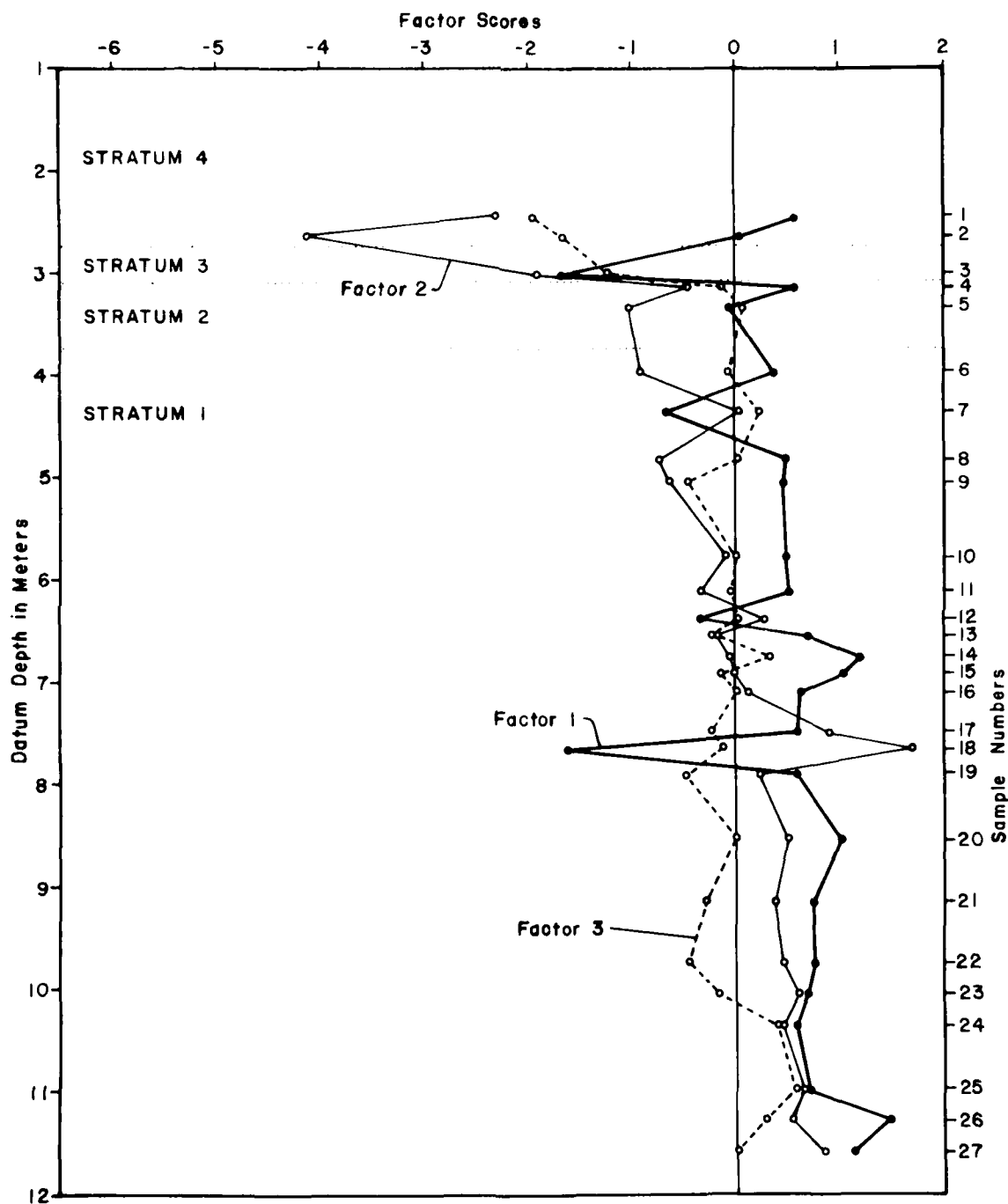


Figure 5.3. Plot of factor scores for Column 3.

Factor 2 has a dichotomous distribution of a high positive loading for pH and a high negative loading for clay, interpreted as primary weathering and soil development, or genesis. pH correlates with depth and is mainly basic while clay has three peaks corresponding also to buried soil profile features; one in the upper part of Stratum 1, a second one in Stratum 2, and a third peak in lower Stratum 4. pH values for lower Stratum 4 are acidic. Birkeland (1974:61) describes an analogous example: "In any weathering environment, the leaching of the cations and the production of hydrogen ion offsets this tendency for most reactions to become basic as weathering proceeds. Grant has shown that the abrasion pH [pH of a distilled water solution with ground aluminosilicate minerals] of weathered material that includes some clay is less than the pH of the original rock, because some cations have been removed, and abrasion pH's of clay minerals commonly are lower than those of the common rock-forming minerals."

Factor 3 has a high negative loading on 31 micron silt opposed to a moderate positive loading on 2 micron silt. Inspection of factor scores plotted by datum depth shows that there are major lateral differences in the importance of one silt fraction over the other, with the 2 micron fraction dominant primarily near the bluff. Factor 3 is interpreted as defining differences in alluvial transport of silt particles due to either silt size or stream velocity. As seen in Columns 3 and 4 (Figs. 5.2, 5.3), the 31 micron silt predominates in the basal part of Stratum 1, when the overbank sediment load appears to have been greatest, and may indicate a high energy stream environment. A high energy environment is inferred also for the top of Stratum 1, probably imparted by high velocity intermittent stream discharge (as reconstructed from sorted, angular alluvial gravels at this level). Similarly, the 31 micron silt peak for mid-Stratum 1 in Column 6 (at 5.85 m) may indicate a localized high energy environment associated with an intermittent channel. At other times the Pomme de Terre River sediment load and velocity appear to have been reduced.

There are at least two ways of going from here to an interpretation of a cluster analysis using the data behind the graphs in Figures 5.1-5.3. Ahler's previous study defined 7 primary clusters representing stratigraphic units with similar depositional histories. It is perhaps not surprising that cluster analyses of each column using the same analytical techniques (Engelman and Fu 1975) defines an optimal, or most readily interpreted, number of eight (Fig. 5.4). Ahler further selected within each group those cases that were stratigraphically contiguous, with the ultimate result of delineating the 11 depositional units previously discussed. A similar solution could be arrived at here but is not attempted. I think a usable alternative would be to focus on river aggradation, the dominant depositional process. Cluster analysis should provide a series of stratigraphically ordered sedimentary units of mainly alluvial origin counterpointed by isolated units of hillslope-derived sediment. Soil formation on Terrace 1b is a secondary process that subsequently affected both alluvial and hillslope-derived sediments. The main questions, I believe, that can be answered by this analysis are: What stratigraphic units shared similar alluvial origins and, secondly, do the major alluvial groups, or clusters, express an order that is

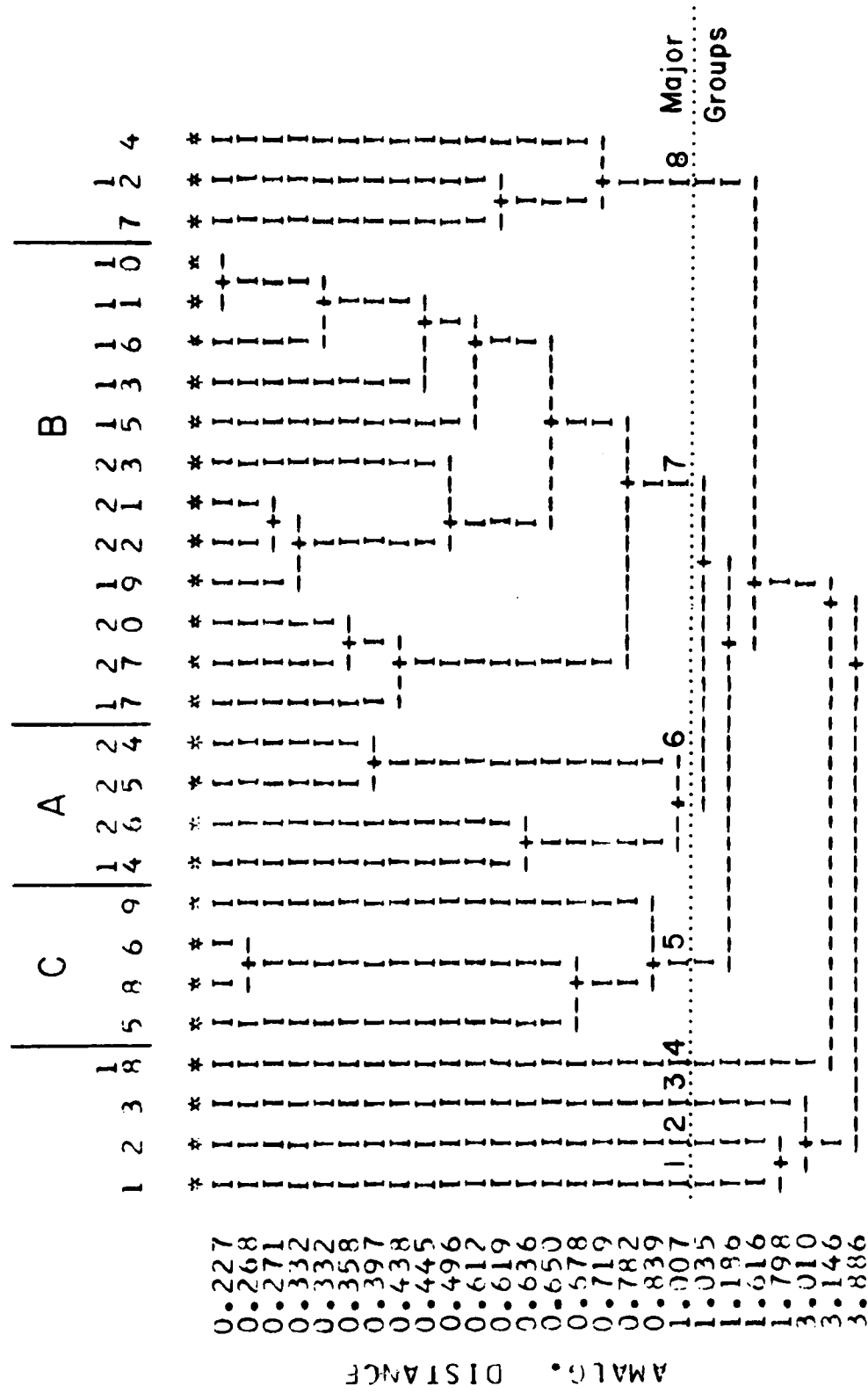


Figure 5.4. Column 3 hierarchical cluster analysis of principal components factor scores using Euclidean distance as means of amalgamation. Eight major groups are delineated, those lettered are mainly of alluvial origin (use numbers refer to Fig. 5.3).

interpretable in terms of changing stream velocities and sediment loads? Correlated questions about the hillslope-derived sediments can perhaps best be approached by analyses discussed in the next section.

Because Column 3 is both least affected by hillslope-derived sediments and contains the longest sedimentary record, it is felt that cluster analysis of its factor scores (Fig. 5.4) will be most definitive of alluvial processes. Three major clusters of alluvial origin are defined, which in Figure 5.4 are labeled A-C. The other four clusters (of seven cases) illustrate hillslope-derived sediments, or a combination of alluvial and colluvial processes. The first cluster of four samples, Group A, contains three cases from less than a meter to a meter above bedrock, and a fourth sample from 4.8 m above bedrock. Group A is interpreted as the basal depositional unit for Terrace 1b, the equivalent of Unit A¹, and is a blue silt of 16-2 micron fractions that formed prior to 10,500 years ago. The characteristic blue color appears to be due to reduction in a water-saturated environment, and is probably post-depositional.

Group B, the second cluster of 12 samples, overlies Group A, with the exception of Sample 27 which is from just above bedrock. Represented is slightly less than 5 m of overbank alluvium having relatively high proportions of 31 micron silt. This could be interpreted to mean a nearer Pomme de Terre channel, greater stream velocities supporting a heavier sediment load than during deposition of Group A, or both. Regardless, Group B records the maximum in vertical accretion by the Pomme de Terre River, probably between 10,500 and 8100 B.P. Group B equates with main excavation Units B², C and basal D.

Group C, the third major alluvial cluster of four samples, overlies Group B and represents about 2 m of sediment. Included are upper Stratum 1 and all of Stratum 2, dating from about 8000 to 5130 B.P. Typical of this cluster is 16-2 micron silt that suggests that the Pomme de Terre has either shifted its channel away from the site or is carrying a lesser sediment load than that of Group B. The slower deposition rate would make the latter alternative the more likely. Soil formation also occurred and the landscape appears to be one of relative stability, at least with respect to the Pomme de Terre River.

Above Group C is a thin Stratum 3 gravel (samples 3 and 4) followed by a Stratum 4 soil (samples 1 and 2) developed on alluvium. Thirty-one micron silt is a dominate textural class of the Stratum 4 samples for this column only, an anomolous situation which probably indicates close proximity to a river channel during deposition of Stratum 4, and possibly Stratum 3, rather than a dramatic increase in sediment load.

Ahler's previous environmental interpretations of alluvial deposition at Rodgers Shelter are largely supported by these analyses. Vertical accretion by the Pomme de Terre, however, continued during the formation of Stratum 3. And, while this area may have experienced minimal precipitation for approximately 1600 years, evidence of drought or drastic change in prevailing climate will have to be judged with respect to hillslope-derived sediments. Then too, three rather than five alluvial units may more efficiently describe river aggradation prior to formation of Stratum 3. Whichever is the case, the basic changes in sediment load are similarly viewed.

NATURAL ROCK DEBRIS ANALYSIS

Until recently, natural rock studies have received little attention by archaeologists. A notable exception is Farrand's (1975) systematic analysis of rock debris from the Abri Pataud. Farrand lists a number of objectives and procedures that augment conventional mechanical and chemical soils analyses, and uses the label *macrogranulometry* to refer to the study of large size rock particles. The Abri Pataud is an Upper Paleolithic cave in France. Many of Farrand's techniques are appropriate for other temperate climate, calcareous cave or shelter sites, or terrace sites at the base of limestone or dolomite hills. Following his example, Rodgers Shelter natural rock debris above 0.5 inch (1.27 cm) diameter was coded for shape, lithology and porosity for standard size grades. Tabulation of secondary deposits typical of cave environments such as travertine did not apply to these sediments. The primary objective was to develop a new source of paleoenvironmental data, as it was with Farrand's study.

Natural rock debris was deposited on the Rodgers terrace by two processes. Frost action along the bluff resulted in accumulation of large, originally angular blocks of dolomite. Secondly, mainly smaller rock fragments were deposited on the floodplain as coarse alluvial fan debris, initially channelized by hillslope runoff into the two hollows on either side of the shelter. Both kinds of rock debris are important to environment and climate studies and impart qualitatively different information. Concentrated frost blocks may indicate cooler or wetter winters, whereas alluvial fan deposits indicate hillslope erosion due to runoff on poorly vegetated slopes. Admittedly, it may be overly simplistic (see below) to assume the causes behind frost action and hillslope erosion so neatly dichotomize prevailing climate. But when added to the data on alluvial depositional processes, it does seem to have some merit.

Generally, hillside vegetation responds to available moisture, conditioned by regional precipitation and retention of soil moisture. Also, the impact of non-climatic factors such as grazing-browsing pressures or fire should not be overlooked. F. King (Chapter 2) notes fire probably had an important role in maintaining upland prairies in this ecotonal area. But charcoal is not prevalent in the major alluvial and hillslope-derived units, except in the context of cultural features such as hearths. The affects of grazing-browsing pressures cannot be assessed.

From field observations, it is known that the Rodgers coarse alluvial fan debris consists of sorted, angular to subangular gravel-sized or larger pieces of dolomite, sandstone or unpatinated chert. Cherts are identifiable to the Jefferson City, Chouteau and Burlington formations which outcrop on the hillside above the site, and the Jefferson City formation cherts are most common. The dolomite and sandstone are from the Jefferson City formation as well. Frost blocks, created by repeated freezing and thawing of water within ever-widening cracks or bedding planes, are observable today at the base of the Jefferson City dolomite bluffs facing the Pomme de Terre River. Fresh frost blocks have angular surfaces and are of variable size. Buried frost blocks at Rodgers Shelter are progressively less angular with age, due mainly to

physical or chemical weathering of surfaces. Field identification of even severely weathered specimens from the talus (Fig. 5.5) creates few problems because the blocks are either highly oriented with respect to the bluff, or are of such size that no process other than frost-and-gravity or an earthquake could account for their presence at the base of the bluff.

The Rodgers strata are notable for both similarities and differences in natural rock clasts. Stratum 1, a compound unit, mirrors the affect of severe frost weathering at its base and, higher up, repeated episodes of hillside erosion. Severe hillslope erosion is represented by Stratum 3. Strata 2 and 4 document frost weathering but to a lesser degree than does the Stratum 1 talus. An important question is, are differences in the kinds and amounts of natural rock clasts statistically significant between strata? And, if so, are they stratigraphically interpretable as reflections of a changing landscape? Discriminant function analysis, a multivariate statistical technique (Cooley and Lohnes 1971), is suitable for evaluating these problems because it attempts to maximize between group variation (i.e., one strata compared to another) while graphically portraying Euclidean distances among groups and, thereby, illustrating diachronically meaningful interstratigraphic similarities or differences.

Sampling

Data for this analysis were generated from the 1976 excavations (Figs. 4.3, 4.4), which about equally and adequately account for frost action along the bluff. Distances to the two hillside hollows on either side of the shelter vary. The west terrace units record proportionately reduced hillslope runoff. All coarse sediments greater than 1.27 cm in diameter from an average matrix volume of $.176 \text{ m}^3$ (i.e., the volume of a five foot square excavated in .25 foot units) were targeted for analysis. The individual excavation levels produced varying but usually large volumes of coarse sediments. In theory, the recording by size-grade the number and weight of lithologies, their shape and porosity of 1.27 cm or larger fractions is simple and straight forward; however, in practice, large sediment volumes make this a laborious and almost impossible task. And, in retrospect, a smaller original matrix of about $.05 \text{ m}^3$ undoubtedly would have produced very similar results and in less time. Of necessity, a stratified random sample of 39 excavation units (Table 5.4) was taken to insure adequate stratigraphic coverage, allowing for complete tabulation by size grade of all coarse sediments greater than 1.27 cm diameter for from three to six excavation units per stratum.

Analysis

Tabulated data for the 39 excavation units consist of number, weight, and volume of size-graded lithologies segregated by shape plus an index of porosity measured for the 1.27 cm diameter debris. (Data on file with the Corps of Engineers, Kansas City District.) Weight and volume correlate above 0.9 for all sediments while number varies with both weight and volume by size grade. Weight in grams for each lith-

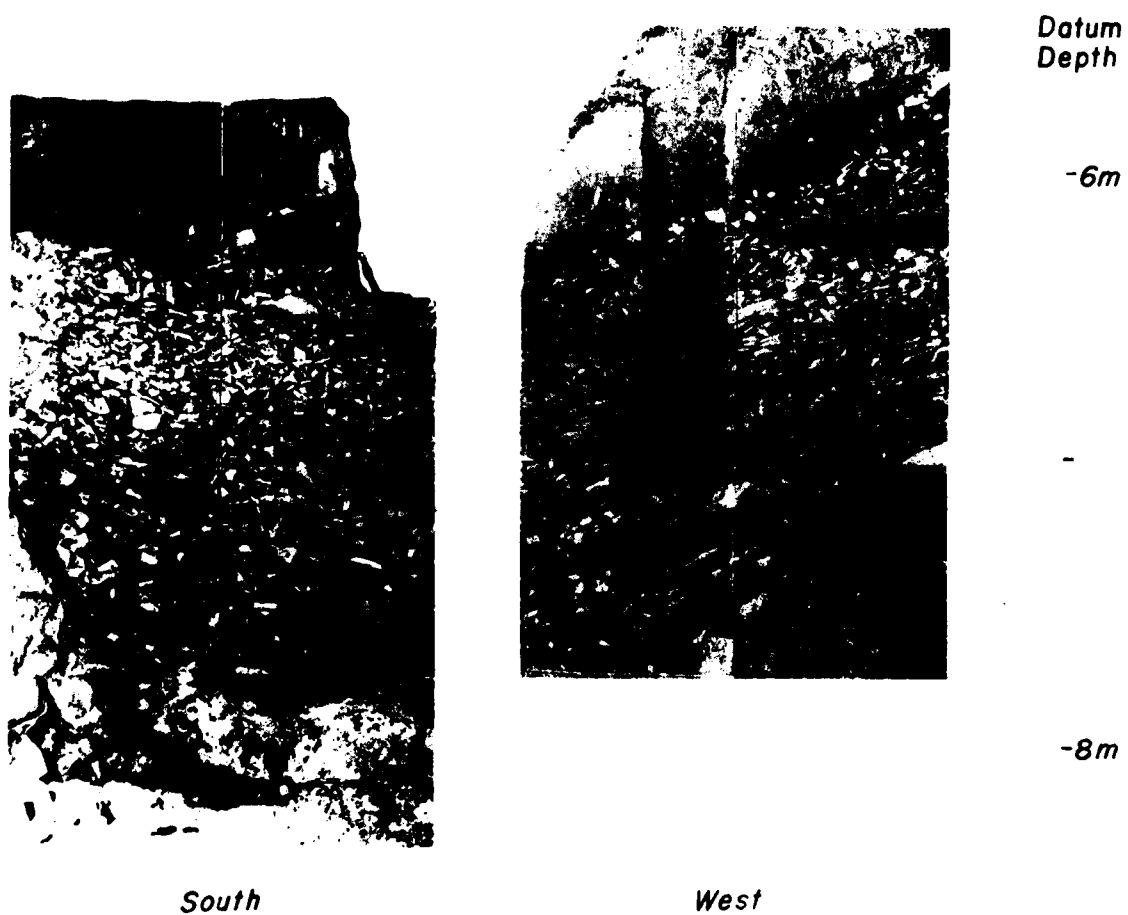


Figure 5.5. Photomosaic of excavation walls near overhang showing talus and lower sediment above bedrock. Note the angular, highly oriented frost blocks of dolomite that compose the talus and the larger boulders above bedrock. Gastropod column visible in west wall.

TABLE 5.4

Macrogranulometry Stratified Random Samples

Catalogue Number	Excavation*	Stratum	Datum Depth (feet)
11028	WT	4	6.00 - 6.25
11032	WT	4	6.25 - 6.50
11037	WT	4	6.75 - 7.00
11039	WT	4	7.00 - 7.25
11049	WT	4	7.50 - 7.75
11053	WT	3	7.75 - 8.00
11068	WT	3	8.00 - 8.25
11103	WT	3	8.75 - 9.00
11107	WT	3	9.10 - 9.25
11119	WT	3	11.50 - 10.75
11131	WT	2	10.75 - 11.00
11197	WT	2	11.25 - 11.50
11318	WT	2	11.35 - 11.45
11324	WT	2	11.75 - 12.00
11359	WT	2	12.25 - 12.50
11388	WT	1	14.50 - 14.75
11532	WT	1	18.75 - 19.00
11545	WT	1	19.25 - 19.50
11553	WT	1	21.25 - 21.50
11584	WT	1	23.00 - 23.25
11046	ME	4	3.45 - 3.70
11089	ME	4	4.20 - 4.45
11099	ME	4	4.45 - 4.66
11102	ME	3	4.66 - 4.91
11108	ME	3	5.50 - 5.75
11110	ME	3	5.76 - 6.01
11114	ME	3	6.26 - 6.51
11116	ME	3	6.50 - 6.76
11163	ME	2	7.82 - 8.07
11172	ME	2	8.07 - 8.17
11188	ME	2	8.42 - 8.67
11273	ME	2	10.17 - 10.42
11310	ME	2	10.92 - 11.17
11333	ME	1	12.17 - 12.42
11353	ME	1	13.96 - 14.35
11461	ME	1	16.50 - 16.75
11470	ME	1	17.50 - 17.75
11527	ME	1	20.25 - 20.50
11571	ME	1	22.75 - 23.00

* WT = West Terrace (Fig. 4.3)

ME = Main Excavation (Fig. 4.4)

ology was used in the final analysis because it was the simplest to calculate and is highly correlated to volume. The total number of variables consists of 110 weights, as explained in Table 5.5, plus a separate series of porosity indices for the 42 1.27 cm diameter lithologies grouped by shape in Table 5.5. Rotated principal components factor scores (Kim 1975) were used as input data for the discriminant function analyses of the weight and porosity data.

Discriminant analysis (Klecka 1975; "direct method") of the porosity data (data not presented) demonstrates that the older materials, particularly the dolomites, are more porous. This is taken to mean that progressively greater physical and chemical weathering has occurred with time, as one should expect. Plot of discriminant scores for the 19 main excavation strata samples (Fig. 5.6) illustrates significant differences in porosity for each strata that are ordered linearly through time. Potentially, this may be important as a relative dating technique for other buried Truman Reservoir sites occurring in Rodgers alluvium.

Of more immediate value, these results indicate that shape must correlate with chemical and physical weathering through time, shape is less indicative of movement prior to deposition and more indicative of post-depositional change. Field observations of natural rock clasts bear this out also. A product of weathering is the pronounced alteration of shape of talus dolomite frost blocks above bedrock, where once acutely angular corners are now almost totally rounded. The hard cherts, however, are less affected by post-depositional weathering. Even so, within each stratum the affects of weathering on all lithologies are less than they are between strata. Thus, shape is not a consistent (i.e., between strata) measure of transport prior to deposition. The factor analysis results also show that shape classifications are ambiguous for the Rodgers terrace as a whole, though various lithologies systematically vary with size grade.

Ideally, fewer variables (weights of lithologies) than cases (samples) should be input into a principal component's factor analysis (Rummel 1970), posing a problem in dealing with the 110 variables for 39 cases used in this study. Three separate principal components (PA1) analyses (Kim 1975; Data on file, Corps of Engineers, Kansas City District) were run using, respectively, 37, 37, and 36 randomly chosen variables from Table 5.5; their rotated factor scores for 34 factors were then entered into a final principal components analysis (Kim 1975, PA1; Data on file, Corps of Engineers, Kansas City District) that, in turn, produced 15 rotated factors whose scores were used as input into discriminant function analysis (Klecka 1975). The discriminant analysis will be discussed later. It will be useful to first review the final principal components analysis as these results succinctly show hillslope conditions and runoff.

Of the 15 rotated factors, the first 10 consist of multiple variables that are potentially explainable in terms of hillslope runoff, frost-and-gravity, main channel deposits or overbank deposits. Only Factor 8 appears to define frost-and-gravity deposition; the others to one degree or another express hillslope runoff and/or colluvial processes. Table 5.6 lists the variables defined by these 10 factors. And, I may note that this is a substantial reduction in keeping with the multivariate "power" of principal components analysis.

TABLE 5.5

Tabulated Variables (weight)

Size-Grade	Quartzite	Oolitic Chert	Banded Chert	Dolomite	Sandstone	Cross- Banded Chert	Choteau Chert	Burling- ton Chert	Cotton- Rock	Calcite	River Gravel	Limestone	Shape
7.62 cm (3 inch)	1 5	2 6	3	4 7 9 11	8							10	Angular Sub-Angular Sub-Round Round
5.08 cm (2 inch)	12 19	13 20 26	14 21 27	17 23 28 31	18 24 29	15	16	22				25 30	Angular Sub-Angular Sub-Round Round
2.54 cm (1 inch)	32 41 52	33 42 53 62	34 43 54	38 48 57 64	39 49 58 65	36 44	37 47	35 45 55	40 51 60 67		45 56 63	50 59 66	Angular Sub-Angular Sub-Round Round
1.27 cm (0.5 inch)	69 81 92 103	70 82 93 104	71 83 94 105	76 87 98 107	77 88 99 108	72	75 86 97	73 84 95	79 90 101 110	80 91 102	74 85 96 106	78 89 100 109	Angular Sub-Angular Sub-Round Round

PLOT OF DISCRIMINANT SCORE 1 (HORIZONTAL) VS. DISCRIMINANT SCORE 2 (VERTICAL). * INDICATES A GROUP CENTROID.

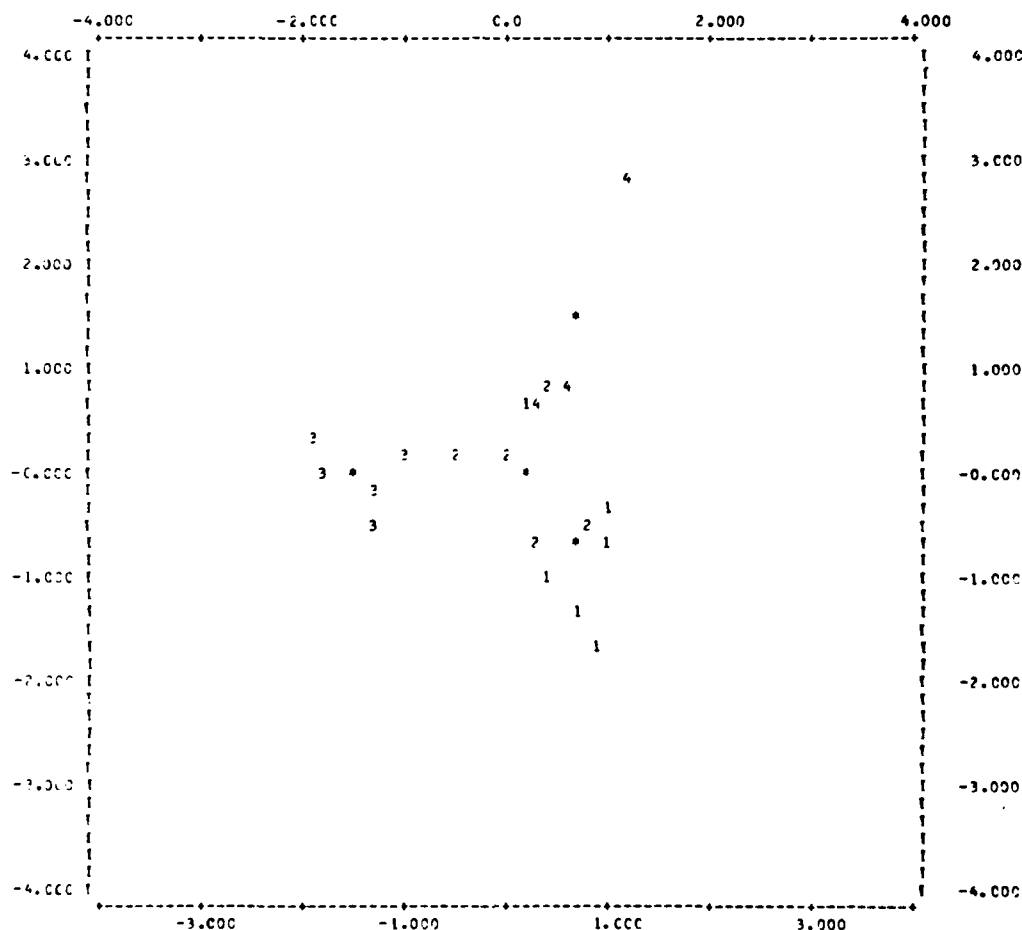


Figure 5.6. Plot of centroids and discriminant scores for main excavation strata (individual samples are numbered by strata) based on porosity factor scores for half-inch size grade lithologies. Dimension 1 separates strata; and Dimension 2 expresses the correct stratigraphic order of the samples, interpreted as a time dimension.

TABLE 5.6

Variables* Defined by First Ten Rotated Principal Components

Number of Variables	Factor									
	1	2	3	4	5	6	7	8	9	10
1	32	3	20	11	4	27	44	25	1	52
2	34	5	72	12	24	49	101	30	2	81
3	40	9	73	22	29	61		59	26	
4	51	14	74	63	38	68		78	46	
5	67	16	95	102	96	88		89	50	
6	71	31			103	104		100	62	
7	75	37						109		
8	76	56						110		
9	79	105								
10	83									
11	90									
12	97									

*See Table 5.5.

Scores for the ten factors (Tables 5.7, 5.8) clearly show that the west terrace and main excavation rock clasts contrast in several important areas. Hillslope runoff components common to the west terrace only include Factors 1, 3, 6 and 10, compared to Factors 3, 5, and 9 for the main excavation. Hillslope runoff, Factor 7, is, however, represented by both excavations. Frost-and-gravity processes (Factor 8) are noted only for the west terrace though, in fact, severe frost weathering is noted above bedrock in both excavations (Figs. 5.5, 5.7); talus units are not represented by the Stratum 1 random samples.

Plotted by datum depth, selected factor scores for each excavation (Figs. 5.8, 5.9) show the affects of runoff correlate highly with Stratum 3, that coarse sediments are more prevalent during and after its deposition. Figures 5.8 and 5.9 show interlayering of coarse Stratum 3 sediments. The basal component for Stratum 3 in both excavations is Factor 7 (i.e., one-inch sub-angular cross banded Jefferson City chert and half-inch sub-round cotton-rock [quartz siltstone]). That three discrete episodes of hillslope runoff are similarly delineated is significant, as are the differences in the two superior Stratum 3 layers. Hillslope runoff within either catchment basin appears to have been of roughly the same magnitude. Probably, what is represented by Stratum 3 are three major rainstorms over a period of 1600 years that progressively stripped the hillside north of Rodgers Shelter of most soils exposing the clayey residuum and bedrock. The differences in lithologies among the later two periods of excessive runoff and erosion may reflect local contrasts in bedrock within the two catchments.

Runoff in Stratum 1 is probably under-represented by this analysis due to sampling limitations. Inspection of profiles for both excava-

TABLE 5.7
West Terrace Factor Scores for Selected Components

Sample	Datum		Factor										Stratum
	Depth(m)	1	2	3	4	5	6	7	8	9	10		
1	1.90	0.45	-0.33	-0.44	-0.29	-0.26	-0.08	-1.86	-0.07	-0.00	4.46	ST4	
2	1.98	-0.12	-0.08	-0.40	-0.26	-0.35	-0.48	0.07	-0.33	-0.30	1.69	ST4	
3	2.13	-0.19	-0.17	-0.19	-0.33	-0.33	0.07	-1.62	-0.14	-0.08	-0.03	ST4	
4	2.20	-0.13	-0.21	0.32	-0.16	-0.05	-0.20	-0.79	-0.19	-0.54	-0.30	ST4	
5	2.36	0.10	5.95	-0.22	-0.55	-0.15	-0.37	0.22	-0.13	-0.43	-0.03	ST3	
6	2.44	0.75	0.14	-0.51	-0.14	-0.21	-0.56	-0.21	0.39	0.12	1.11	ST3	
7	2.50	5.47	-0.22	-0.30	-0.23	-0.03	-0.13	-0.88	0.02	-0.18	-0.35	ST3	
8	2.74	1.82	-0.52	0.38	0.23	-0.44	-0.06	3.44	-0.00	-0.66	-0.90	ST3	
9	2.81	-0.16	-0.42	-0.51	-0.05	-0.31	-0.64	0.30	-0.27	-0.19	-0.51	ST3	
10	3.27	0.19	-0.38	-0.54	0.12	-0.28	0.25	0.93	-0.34	-0.10	-0.42	ST3	
11	3.35	-0.42	-0.19	-0.65	-0.21	-0.27	-0.23	-0.21	-0.24	-0.17	-0.14	ST2	
12	3.50	-0.32	-0.52	-0.53	-0.61	-0.25	0.90	-0.72	-0.34	-0.38	-1.13	ST2	
13	3.49	-0.53	-0.20	-0.07	-0.31	0.17	-0.29	-0.24	-0.30	-0.10	-0.33	ST2	
14	3.65	-0.39	-0.08	-0.27	-0.27	-0.40	0.10	-0.36	-0.18	-0.13	-0.28	ST2	
15	3.80	-0.38	-0.09	-0.17	-0.02	-0.17	-0.17	-0.13	6.01	-0.19	-0.27	ST2	
16	4.49	0.04	0.19	0.92	-0.02	-0.09	5.61	0.11	0.08	-0.16	0.56	ST1	
17	5.79	-0.46	-0.18	-0.90	-0.20	-0.16	0.14	0.40	-0.23	-0.26	0.85	ST1	
18	5.94	-0.39	-0.09	-0.20	-0.52	-0.09	0.83	-0.50	-0.22	0.16	-0.24	ST1	
19	6.55	-0.47	-0.23	-0.06	-0.30	-0.36	-0.53	-0.34	-0.27	-0.01	-0.21	ST1	
20	7.08	-0.34	-0.26	-0.19	-0.33	-0.05	-0.27	-0.07	-0.47	0.17	-0.08	ST1	

TABLE 5.8
Main Excavation Factor Scores for Selected Components

Sample	Datum										Stratum	
	Depth(m)	1	2	3	4	5	6	7	8	9		10
1	1.12	-0.18	0.47	-0.54	5.88	-0.13	0.14	-0.41	-0.21	0.23	-0.47	ST4
2	1.35	0.01	0.00	-0.15	-0.01	5.86	0.01	0.06	-0.00	0.18	-0.18	ST4
3	1.42	-0.53	0.00	-0.42	-0.10	0.00	-0.34	0.18	-0.09	-0.78	0.52	ST4
4	1.49	0.04	0.26	3.41	-0.13	-0.80	-0.11	-0.56	-0.09	0.23	-1.30	ST3
5	1.75	0.09	-0.23	4.38	0.33	0.44	-1.33	0.07	-0.08	-0.40	1.20	ST3
6	1.83	0.14	0.20	-0.02	-0.37	-0.14	-0.03	0.15	0.06	5.72	-0.15	ST3
7	1.98	-0.29	-0.36	0.40	0.42	-0.65	-0.49	2.33	-0.09	1.03	0.83	ST3
8	2.06	-0.41	-0.04	0.17	-0.36	0.34	0.38	2.56	-0.01	-0.34	1.38	ST3
9	2.45	-0.43	-0.20	-0.48	-0.15	0.26	-0.13	0.58	-0.14	-0.39	0.22	ST2
10	2.49	0.00	-0.33	0.46	0.04	0.25	-0.13	-1.32	-0.09	-0.49	-1.06	ST2
11	2.64	-0.28	-0.25	0.29	0.24	0.23	-0.52	-0.60	-0.12	-0.30	-0.66	ST2
12	3.17	-0.13	-0.10	-0.41	-0.00	0.09	0.19	-0.19	-0.04	-0.32	-0.49	ST2
13	3.40	-0.31	-0.25	0.51	0.00	-0.18	-0.32	0.07	-0.19	-0.43	-0.52	ST2
14	3.78	-0.38	-0.23	0.03	-0.13	-0.31	-0.31	-0.33	-0.26	-0.15	-0.32	ST1
15	4.37	-0.37	-0.12	-0.06	-0.30	-0.48	-0.17	-0.48	-0.27	-0.32	-0.46	ST1
16	5.10	-0.51	-0.19	-0.57	-0.28	-0.36	-0.27	-0.35	-0.25	-0.15	-0.42	ST1
17	5.41	-0.50	-0.20	-0.58	0.28	0.34	0.26	-0.34	-0.25	-0.16	-0.40	ST1
18	6.24	-0.44	-0.27	-0.44	-0.13	-0.02	-0.29	0.07	-0.29	-0.19	-0.30	ST1
19	7.01	-0.35	-0.11	-0.55	-0.70	0.09	-0.07	-0.72	-0.35	0.70	-0.65	ST1

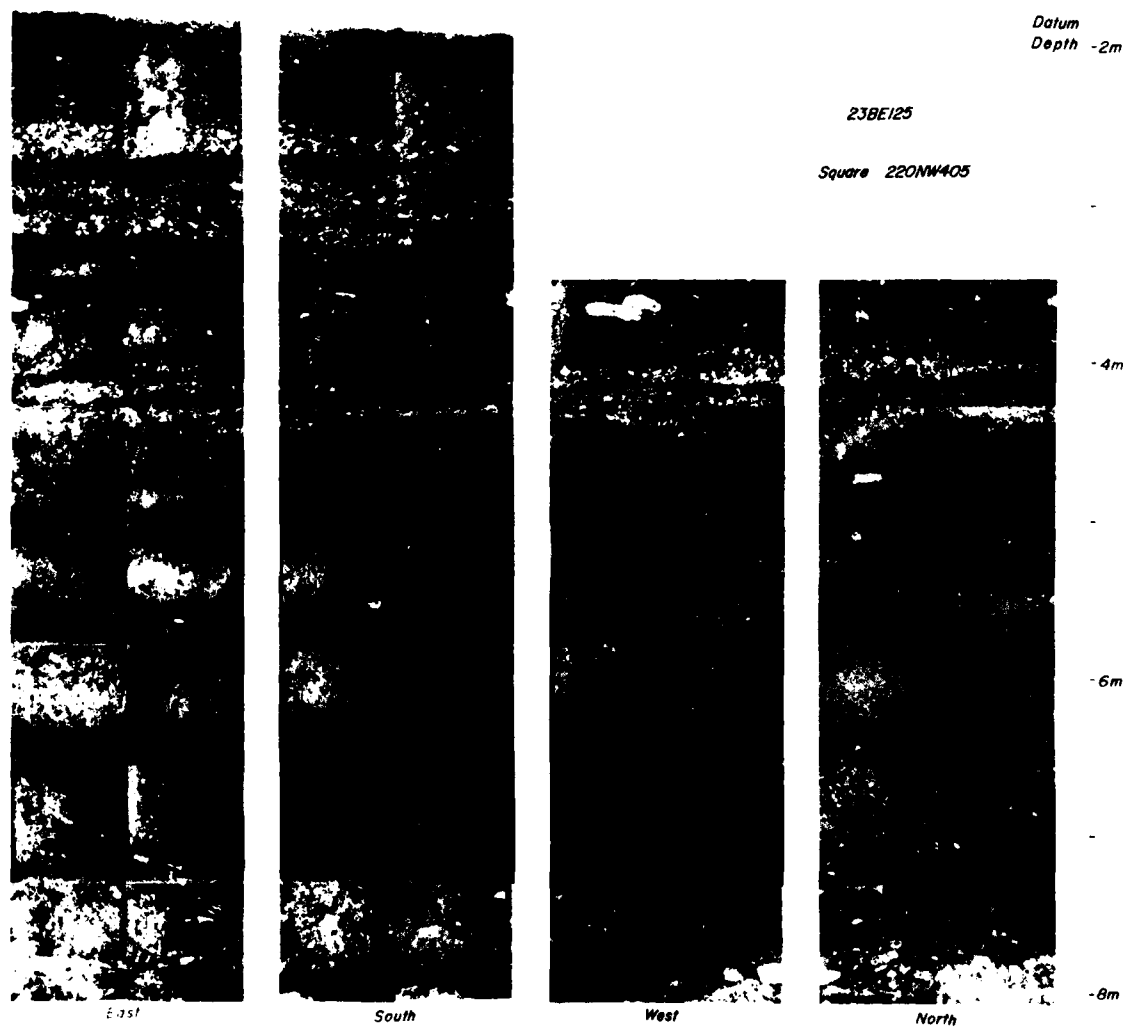


Figure 5.7. Photomosaic of west terrace excavation; note Stratum 3 (about 3 m below datum) and upper Stratum 1 (4 m below datum) coarse, hillslope-derived sediments and basal talus formed by severe frost weathering of bluff. Stratum 2 (about 3.5 m below datum) also has numerous frost blocks.

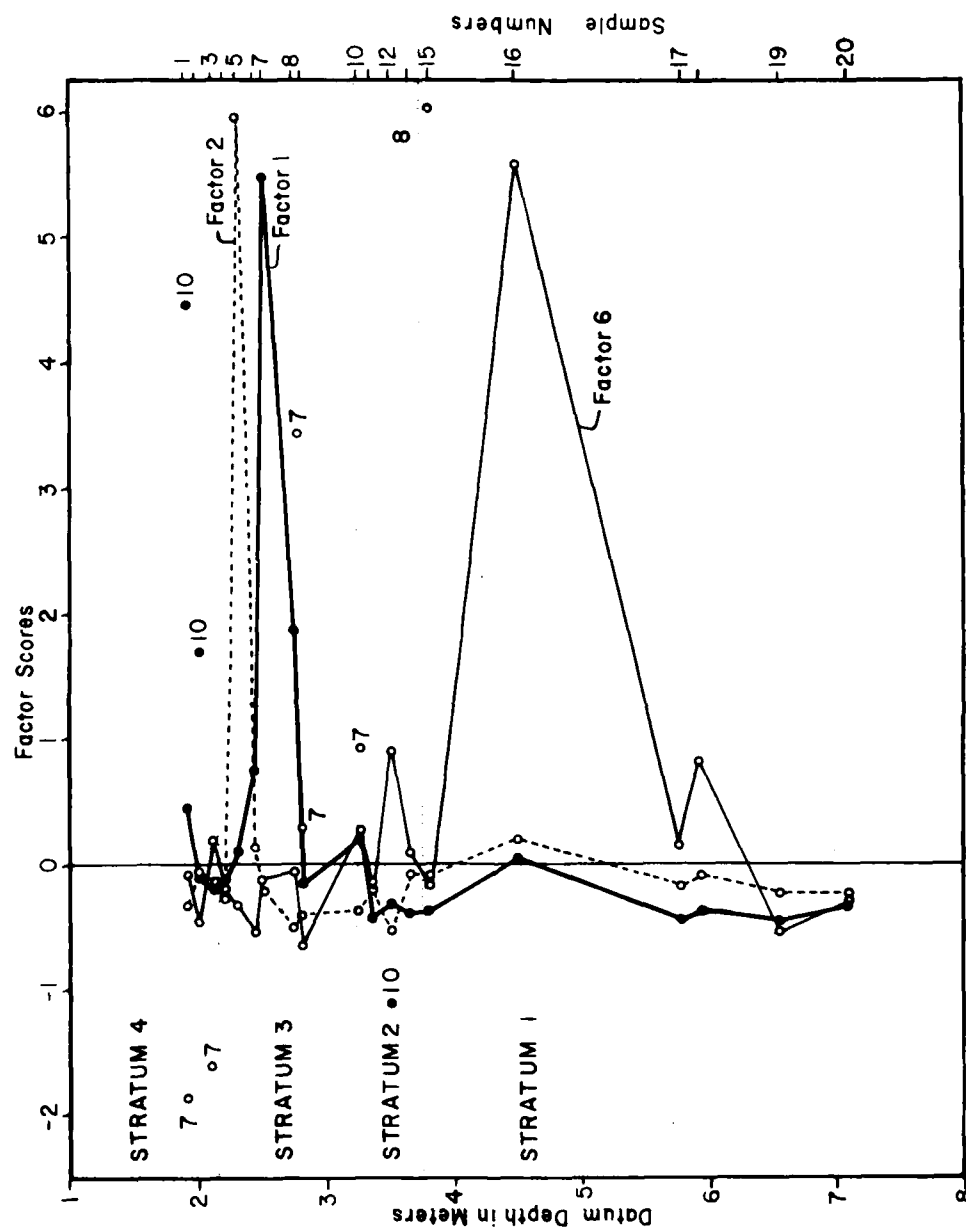


Figure 5.8. Plot of selected factor scores for west terrace excavation showing major affects of hillslope runoff. Magnitude of hillslope runoff is approximately the same for Strata 1 and 3; Stratum 3 shows three peaks in runoff, defined by stratigraphically different lithologies that correspond to field observations (Fig. 5.7). Factor 8 defines the affects of frost-and-gravity.

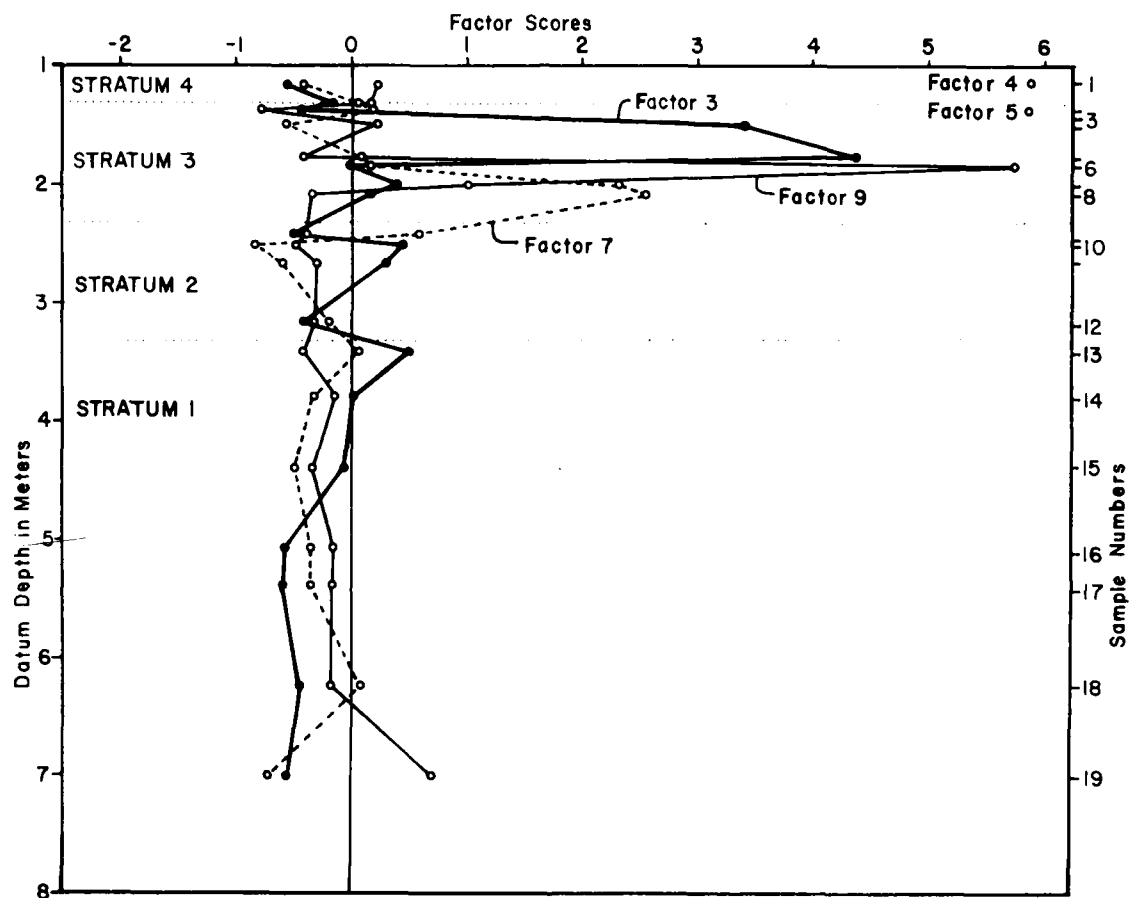


Figure 5.9. Plot of selected factor scores for main excavation showing major affects of hillslope runoff. Runoff in Stratum 3 is stratigraphically separable into three components, as do the clasts for the west terrace Stratum 3 samples. Note as well that Factor 7 is stratigraphically the lowest component as it is on the west terrace. Differences above this probably express local contrasts in bedrock and hillside residue. Magnitude of runoff is comparable to the west terrace.

tions (Figs. 5.7 and 3.5) show that coarse debris is present but in lesser amounts than in Stratum 3. Factor 6, noted only on the west terrace, shows that comparable sediment loads were transported. The lithologies (sub-rounded banded chert, sub-angular and round calcite, sub-angular sandstone and oolitic chert) are all from the Jefferson City formation, indicating that erosion was contained to the lower hillslopes, whereas Stratum 3 coarse sediments are from the hillcrest and upper slopes as well. This is to say that hillslope erosion was greatest during deposition of Stratum 3 though runoff velocities and sediment loads may have been very similar to those of Stratum 1.

Frost weathering is again under-represented because of sampling limitations, but it is clear that at least minor frost action occurred during Stratum 2 deposition, as seen by Factor 8 (Fig. 5.8).

Final suites of coarse hillslope sediments are represented by Factors 4 and 5 (main excavation) and 10 (west terrace) for Stratum 4, exclusively. On the west terrace, these consist of highly resistant Jefferson City quartzites and sandstones. In addition, the main excavation lithologies include Burlington formation chert, calcite, dolomite, and river gravel. With the exception of the river gravel, all appear to be derived from bedrock rather than the clayey bedrock residuum, which was largely stripped off during Stratum 3 deposition. (A possible source of "river" gravel is a pre-Pleistocene patinated gravel seen on hill crests in the lower Pomme de Terre locality; this may also account for the patinated gravel in the main excavation Stratum 3 deposits, also labeled "river gravel".)

Three discriminant analyses (Klecka 1975; "direct method") were run using the 15 rotated factor scores. All produced statistically significant discrimination among strata, conclusively rejecting the null hypotheses that variation in coarse lithologies was no more than due to chance. As discussed above, interrelated factors of hillslope runoff and progressive erosion are responsible. The first discriminant analysis dealt with both excavations, the latter two with each excavation separately. The data and results of the west terrace analysis will be presented in the interest only of not needlessly engaging in repetition.

The west terrace analysis produced three discriminant dimensions respectively, accounting for 57.3 percent, 30.7 percent, and 16.0 percent of the total variation. All have canonical correlations greater than 0.91 and the first two are statistically significant (Table 5.9). All cases (samples) were correctly classified for each strata, as clearly shown by the plot of group centroids (multidimensional means of each strata) and discriminant scores for each case (Fig. 5.10). Figure 5.10 defines the Euclidean distances among groups (strata). It should be noted that natural rock clasts of Stratum 1 are most similar to Stratum 2; that Stratum 3 is dissimilar to all the other strata defined primarily by Dimension 1. This plot of discriminant dimensions is a precise analytical model of Euclidean distances among strata, comparable to the principal components analysis, and shows progressive changes in hillslope morphology.

TABLE 5.9

Discriminant Analysis

Discriminant Function	Eigenvalue	Relative Percentage	Canonical Correlation
1	17.01	53.30	0.97
2	9.80	30.70	0.95
3	5.10	16.00	0.91

Functions Derived	Wilks' Lamda	Chi-Square	DF	Significance
0	0.0008	67.261	45	0.017
1	0.0152	39.796	28	0.069
2	0.1637	17.189	13	0.191

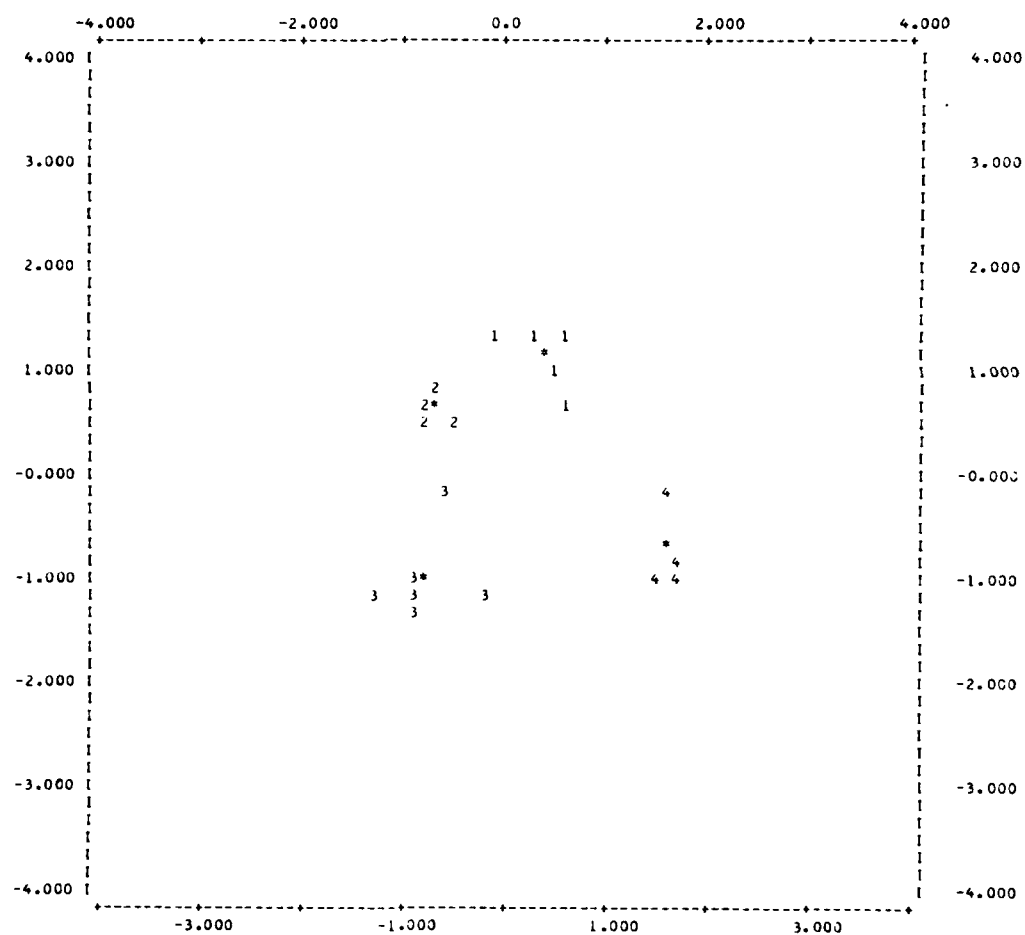
DISCUSSION AND SUMMARY

Drawing together all the information on depositional processes, rates of sedimentation and landscape stability, we can see that the alluvial processes must mirror regional conditions during the early to mid-postglacial. The slowing deposition rates, changes in silt fractions through time indicate reduction in stream flow after 8100 B.P. The riparian landscape became relatively stable from about 8100 to 5700 B.P., a period of probably reduced precipitation. Hillslope conditions were not similarly stable and shortly after 5100 B.P., the first of three major intervals of erosion occurred. These, by 3600 B.P., had virtually stripped all soil from the hillside north of Rodgers Shelter, rapidly exposing bedrock on the steeper slopes. After 3600 B.P. edaphic conditions on the hillslopes were impoverished. Upland glades, or oak barrens, probably became well established about this time.

Affective hillslope runoff changed radically from, say, 9000 B.P. to the interval between 5200 and 3600 B.P. This, I believe, indicates that the hillslope vegetation became a less effective check against erosion in the mid-postglacial, marking the onset of drier conditions that culminated with deposition of Stratum 3. Similar, severe erosion and eolian deposition of coarse sediments was recently brought about by prolonged drought in the Sierra Nevadas of California followed by a major rain and windstorm that dumped as much as five feet of sand in the San Joaquin basin. Other causes, such as burning, grazing-browsing pressures, more intense human occupation of the valley, all may have contributed to the environmental impact of declining precipitation and sustained drought, a climatic regime still seen along the southern Prairie Peninsula border.

Whatever are the causes, the changes in the Ozark Highland landscape during the Holocene suggest finite limits to the application of biotic resource models (Chapters 2, 7-9). Particularly, the vegetation of upland Ozark valley slopes may well have reached its climax state

PLOT OF DISCRIMINANT SCORE 1 (HORIZONTAL) VS. DISCRIMINANT SCORE 2 (VERTICAL). * INDICATES A GROUP CENTROID.



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relatively late in the Holocene. Secondly, it probably will be difficult, if not impossible, to take early historic vegetation data, no matter how well collected, and apply it as a resource model for the mid-postglacial or earlier Holocene cultural manifestations such as Dalton.

To summarize briefly, most rapid accumulation occurred during the deposition of Stratum 1, from 10,500 to 8100 B.P., primarily in the form of Pomme de Terre overbank alluviation of roughly 5.5 m of silt. This period represents radical changes in regional landscape that followed an abrupt transition from glacial to interstadial conditions and began with colder climates. We can hypothesize the filling of deep, incised or scoured Pleistocene river valleys, progressive denudation of thickly mantled, forested hillslopes; deep burial of alluvial, early Holocene cultural components in a relatively short interval. Deposition after 8100 B.P. slowed and was punctuated by a cut-and-fill sequence about 7500 B.P. and development of a paleosol. Approximately 1.5 m of mainly alluvium was added to the top of Stratum 1, was eroded away in channeled areas and subsequently refilled after 7500 B.P., during the formation of Stratum 2. Unit D (upper Stratum 1) marks the onset of the mid-postglacial "climatic optimum," or Hypsithermal (as redefined by Wright 1976), primarily noted for reduced precipitation (King and Allen 1977), and establishment of tall grass prairies on the western flank of the Ozarks (McMillan 1976:229). At Rodgers, prairie habitats persisted at least until the end of Stratum 2, and perhaps later during the interval of Stratum 3 deposition from 5200 to 3600 B.P. Unit D represents a cultural florescence that continued during deposition of Stratum 2. From 7500 to 5200 B.P. only 1 to 1.5 m accumulated as Stratum 2 sediments, a period of increased, effective frost activity along the southerly facing bluff, but less severe than during initial Dalton occupation. There was a radical departure from the preceding depositional environment after 5200 B.P. Vertical accretion of the Pomme de Terre, however, continued to dominate and was the controlling factor of Stratum 3 deposition; from all sources about 1 m of sediment was added to the floodplain. Colluvium or coarse hill-slope derived alluvial fan deposits affected the toe-of-slope topography. This, together with increased aridity, was probably a prime cause leading to the cultural abandonment of Rodgers Shelter for about 1600 years during which the hillslopes were progressively denuded of vegetation and soil. Bedrock was widely exposed. The Stratum 3 deposition rate was roughly maintained during early Stratum 4 accumulation, with a meter or less added about 3600 to 2400 B.P. Deflation of Terrace 1b occurred after 3600 B.P. and is represented on the west terrace by a basal Stratum 4 date of 2617 ± 41 B.P. (SMU-465). Markedly reduced rates of colluvial and alluvial deposition have occurred since 2240 B.P., resulting in but minor increments of sediment and generally poor separation among Stratum 4 Late Archaic and Woodland components.

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CHAPTER 6

ETHNOBOTANICAL REMAINS FROM RODGERS SHELTER

Frances B. King

Plants play a vital role in the diet of both hunting and gathering peoples, forming a stationary and relatively dependable source of food. The exact importance of plant foods varies with the geographical region (based on the relative abundance of plant and animal foods) and the season. Relatively higher energy plant foods are available in the fall for little effort, while in the spring or summer, plant foods are low in food value and animal resources are more desirable.

There are more than 200 plants in the Truman Reservoir area with one or more edible parts (King 1976). Many of these plant foods lack any potential of being preserved in the archaeological record, while others possess durable shells or seeds which are readily preserved. When attempting to reconstruct subsistence activities on the basis of botanical remains, we are naturally biased toward the readily preserved plants and can say nothing about the total diversity of plants used or the absolute importance or use of any single plant species. Within this framework, however, much can be done to construct patterns of plant utilization that can be combined with faunal and other archaeological data to produce an otherwise impossible projection of aboriginal subsistence strategies. It is toward this goal that we have worked during the analysis of the plant remains from Rodgers Shelter.

METHODS

Excavations have been conducted at Rodgers Shelter twice since the data reported in Parmalee *et al.* (1976) were collected. During the summer of 1974, the equivalent of a five foot square was excavated under the overhang to a depth of approximately six feet where it bottomed out on a rock slab fallen from the roof of the shelter. The excavation was conducted under the direction of Kerry McGrath. Prior to the field season, the area chosen for excavation was about half removed by pot hunters. In order to excavate a volume of material approximately that of a five foot square, which was chosen as an adequate sample size, an additional 2.5 x 5 foot square was located adjacent to the original square on the east and excavated to the depth of the hole dug by the pot hunters. Still, the volume to be excavated was uncertain and varied with depth because of the irregular shape of the previously dug hole. In order to correctly ascertain the precise volume of material excavated for each level, the squares were excavated into 7.5 liter containers prior to screening through 1/4" mesh to remove rocks, mussel shells, artifacts and other relatively large items. The matrix was then dried to facilitate disaggregation in water flotation. When dried, the matrix was taken to the river where small quantities were placed in tubs, the bottoms of which had been replaced by 1/16" mesh (Struever 1968). Initially, the flotation was accomplished by wading into the river about waist deep carrying an empty float tub and a second person would pour the dry matrix into the

tub while the first person sloshed and shook it. Soil particles fell through to the bottom and washed out through the screen. Charcoal floated and was skimmed off by the second person. After the matrix was completely disaggregated, all fine soil particles removed and charcoal no longer floated, the material was removed from the tubs and once again dried. Ultimately, all material was also hand sorted.

Later we found it was feasible to place the tubs in shallow water with a rock propping up the upstream side. When situated in this manner, the velocity of water entering the tubs from beneath created more than sufficient turbulence to float plant materials and to disperse the matrix. Thus, twice as many tubs and twice as much material could be floated at one time.

In 1976, the considerably more sophisticated technique was to wash the dried and trisodium phosphate treated matrix through a large set of nested screens, with the small size fraction being ultimately processed in float barrels (Watson 1976). Although not necessarily improving on the quality of the recovered materials, the large scale screening and floating operation allowed for the much more rapid field processing of matrix necessitated by the large volume of material excavated. Although outdoor water flotation has sometimes been condemned because of the possibility of contamination, a moist site such as Rodgers Shelter offers little chance for preservation of non-carbonized plant materials. The likelihood of carbonized remains being inadvertently added to the samples by flotation with river water in the absence of upstream burning is also negligible. In addition, there has been a great deal of disturbance at Rodgers Shelter by burrowing rodents and insects. As a result, many fresh or non-carbonized seeds were included in the matrix, and all such seeds should be disregarded.

Laboratory sorting of the washed and size graded matrix followed the field season. Sorting was facilitated by size grading, in that it is much easier to sort for a limited size range of seeds or nuts than it is to sort for all possible types and sizes simultaneously. Figure 6.1 shows a typical distribution of seeds in the different size classes, as well as the form used in sorting and identifying the 1976 materials. All seeds were identified and counted whether they were carbonized or not.

Non-carbonized seeds were initially identified by sorters based on a reference collection of seeds from Rodgers Shelter and later verified by the author.

All carbonized material was separated from the non-carbonized and underwent examination and identification by more experienced workers. Identifications were made by comparisons with the seeds collection of the Illinois State Museum Quaternary Studies Center and several published references (primarily Martin and Barkley 1961; Delorit 1970; Montgomery 1977; USDA 1974). The ecological field studies conducted during the summer of 1976 to build biotic models of the area proved very useful by producing lists of the plants in the areas that were potential seed sources, as well as reference material.

Charcoal was also identified to the lowest possible taxonomic level. Some experimentation was done with identifying charcoal by imbedding in resin and thin sectioning on a microtome. This is a desirable technique since carbonization can alter the size and structure of wood cells such



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FLORAL REMAINS FROM RODGERS SHELTER-1976

CHARCOAL	1/4	1/8	1/16	1/16	Total
Charcoal	.49	6.13	15.35	—	21.88
Hickory nuts					
Walnuts					
Acorns					
Hazelnuts					
Others					
Total					

Celtis, C					
Celtis, U					

Figure 6.1. Sample coding sheet for Rodgers Shelter floral material.

that they cannot be correctly identified on the basis of gross anatomy (Smith and Gannon 1973; Dimbleby 1967). However, working in the depauperate oak hickory forest of western Missouri (Braun 1950) has some advantages, one of which is potential representation of only a relatively few taxa in the archaeological record. Most of the wood types present in western Missouri are readily identifiable to at least the generic level, even when carbonized. Since identification of wood by gross anatomical features of the cross-section is much less time consuming than thin-sectioning, most Rodgers Shelter charcoal identifications were from cross sections made by snapping a charcoal fragment in half as were those from Phillips Spring. Ideally, at least twenty identifications were desired for each sample. This was possible only for the upper horizons. At greater depths, an attempt was made to identify each piece of charcoal, and twenty identifications were still not possible in all horizons. Identifications were made through comparisons with modern wood specimens and with the key and figures in Panshin and DeZeeuw (1970).

RESULTS

SEEDS

A total of nearly 28,000 uncarbonized seeds representing 31 taxa and 100 carbonized seeds were recovered from Rodgers Shelter in the 1974 and 1976 excavations (Tables 6.1 to 6.3). Although the uncarbonized seeds are probably meaningless for archaeological reconstructions, they do reflect the environment of the shelter as we know it today. The same or similar taxa may well have occurred in the area for much of the last few thousand years. The trees reflected in the seed rain include bottomland species such as sycamore, species characteristic of the lower slopes (hawthorne, dogwood, redbud), the upper slope (red cedar), and disturbance (persimmon). The majority of the seeds of shrubs and herbaceous plants represent either the slope or disturbance communities. Those representing the slope forest include smooth sumac, poison ivy, grape, greenbriar, violet, buckbrush, bedstraw, and bush clover (Tables 6.1 to 6.3). Those that are derived from disturbance of the floodplain are pigweed, lambsquarter, grass, pokeberry, knotweed, buffalo bur, sunflower, sedge, wild carrot, ragweed, dock, mullein, and wild mustard. In addition, the seeds of plants found in Juniper glades above the shelter are abundant, doveweed and spurge especially. The west terrace is more exposed and had more seeds and seed types than did the protected area adjacent to the shelter. The number of carbonized seeds and seed types is also greater on the west terrace where there are thirteen types compared to the shelter where there are only ten (Table 6.4).

West Terrace

There are three types of carbonized seeds which are present at the shelter and also on the west terrace: grape, buffalo bur and lambsquarter. Buffalo bur (*Solanum rostratum*, also known as Kansas thistle) is a drought resistant, bristly weed with bristle covered, globe shaped berries which might easily get entangled in clothing or fur. Grape (*Vitis* sp.) is a common vine in both upland and bottomland situations and produces edible fruit. Lambsquarter (*Chenopodium* sp.) is a disturb-

TABLE 6.1

Uncarbonized Seeds Recovered from 1974 Excavations
at Rodgers Shelter (4379 total)

Species	Horizon						Total
	1	2	3	4	5	6	
<i>Amaranthus</i> sp. (Pigweed, Amaranth)	167	152	49				368
<i>Ambrosia trifida</i> (Giant ragweed)	1	1					2
Caryophyllaceae (Pink family)	4	4	1	1	59	2	71
<i>Chenopodium</i> sp. (Lambsquarter)	18	2	76				96
<i>Crataegus</i> sp. (Hawthorne)	12						12
Cruciferae (Mustard)	1						1
Cyperaceae (Sedge)	65	58	19				142
<i>Datura stramonium</i> (Jimson weed)	87	82	12				181
<i>Daucus carota</i> (Wild carrot)		32	2				34
<i>Diospyros virginiana</i> (Persimmon)	1						1
<i>Galium</i> sp. (Bedstraw)	1		18				19
Gramineae (Grass)	89	8	30		1		128
<i>Juniperus virginiana</i> (Red cedar)			1				1
<i>Phytolacca americana</i> (Pokeweed)	1377	635	39				2051
<i>Polygonum</i> sp. (Knotweed)	17	4	13				34
<i>Rubus</i> sp. (Blackberry, etc.)	2		1				3
<i>Rumex</i> sp. (Dock)	1	1	1				3
<i>Sambucus canadensis</i> (Elderberry)	86	260	8				354
<i>Solanum rostratum</i> (Buffalo bur)	400	322	142	1			865
<i>Vitis</i> sp. (Grape)	10	3					13
Total	2339	1564	412	2	60	2	4379

ance plant producing edible greens in the spring and edible seeds in the fall. Caches of lambsquarter seeds have been found at several sites in the midwest (Asch and Asch 1977).

Other carbonized plant remains on the west terrace include:

Redbud (*Cercis canadensis*), a small, leguminous tree producing pink flowers and pea-like pods. Both the flowers and the young pods are edible and the Navajo ate the seeds of the similar *Cercis occidentalis* (Yanovsky 1936). The seeds mature on the trees from July to September.

Knotweed (*Polygonum* sp.), two sizes of carbonized knotweed seeds were recovered at Rodgers Shelter; a large, triangular achene approximately 3 mm in length, possibly *P. scandens*, and a smaller type, probably either *P. ramossissimum* (bushy knotweed), *P. punctatum* (water smartweed), or *P. sagittatum* (arrow-leaved tear-thumb). All of these species occur in a variety of habitats including rich, moist, bottomland such as occurs at Rodgers Shelter. Bushy knotweed has variable achenes measuring from 2.2 to 6.5 mm depending on the season and the part of the plant on which it is grown. It is thus entirely possible that all of the seeds present are of the same species.

Poison Ivy (*Rhus radicans*), a common bottomland vine containing a volatile oil which causes allergic reactions of varying degrees. The

TABLE 6.2

Uncarbonized Seeds Recovered from 1976 Excavations at Rodgers Shelter
Main Excavation Area (4783 total)

Species	1	2	3	4	5	6	7	8	9	10	Total
<i>Amaranthus</i> sp. (Pigweed)	275	869			3	1		4		2	1154
<i>Ambrosia artemisiifolia</i> (Common ragweed)				1							1
<i>Caryophyllaceae</i> (Pink)	31	43	15	3	13				1		106
<i>Chenopodium</i> sp. (Lambsquarter)	596	139		52	15	1		1			804
<i>Cornus</i> sp. (Dogwood)					23						23
<i>Croton</i> sp. (Doveweed)											
Cyperaceae (Sedge)											
<i>Daucus carota</i> (Wild carrot)											
<i>Euphorbia</i> cf. <i>corollata</i> (Spurge)					1				1	16	18
<i>Galium</i> sp. (Bedstraw)		2									2
Gramineae (Grass)	22	40		8	8	7	2	9	21	25	142
<i>Helianthus</i> sp. (Sunflower)		8			1						9
<i>Juniperus virginiana</i> (Red cedar)	4	2	30	6		1		1			44
Labiatae (Mint)										1	1
<i>Lespedeza</i> sp. (Bush clover)						1					1
<i>Phytolacca americana</i> (Pokeweed)	423	1080	850	26	24	6		8	7		2424
<i>Polygonum</i> sp. (Knotweed)										1	1
<i>Rhus glabra</i> (Smooth sumac)				1							1
<i>Rumex</i> sp. (Dock)		1				1	1				3
<i>Sambucus canadensis</i> (Elderberry)		2	1		1		1				5
<i>Solanum rostratum</i> (Buffalo bur)		1		3	9	1			3	2	19
<i>Viola</i> sp. (Violet)	7	2	1		1	1		2	3	2	19
<i>Vitis</i> sp. (Grape)	2		1						2	1	6
Total	1360	2189	898	100	99	20	4	25	38	50	4783

TABLE 6.3

Uncarbonized Seeds Recovered from 1976 Excavations at Rodgers Shelter
West Terrace (18,533 total)

Species	Horizon											Total
	1	2	3	4	5	6	7	8	9	10	11	
<i>Ambrosia artemisiifolia</i> (Common ragweed)	24				1							26
<i>Ambrosia trifida</i> (Giant ragweed)								1				2
<i>Caryophyllaceae</i> (Pink)	678	1					1					680
<i>Chenopodium</i> sp. (Lambsquarter)	1688	1		2		1	1	1	1			1694
<i>Crataegus</i> sp. (Hawthorne)	76			3	1							80
<i>Croton</i> sp. (Doveweed)	9845	520	65	38	53	2	2	30	1	10		10596
<i>Cruciferae</i> (Mustard)								1		1		2
<i>Daucus carota</i> (Wild carrot)	27	3		1		1	5	4				41
<i>Diospyros virginiana</i> (Persimmon)			1									1
<i>Euphorbia</i> cf. <i>corollata</i> (Spurge)	346	8		7	1		3			1	2	368
<i>Galium</i> sp. (Bedstraw)	86	6	12	13	6	2	3	1				129
<i>Gramineae</i> (Grass)	113	5	1	18	30	4	4	33		19	2	229
<i>Juniperus virginiana</i> (Red cedar)		1			1					1		3
<i>Lespedeza</i> sp. (Bush clover)	519	2	9	20	15	1		3		6		575
<i>Phytolacca americana</i> (Pokeweed)	1310	7	4	4	7	1				3		1336
<i>Platanus occidentalis</i> (Sycamore)	25	2	14		1	1		9	1	22		75
<i>Polygonum</i> sp. (Knotweed)	22	3	3	17	13	1			1	53	2	115
<i>Rhus glabra</i> (Smooth sumac)	4		2									6
<i>Rhus radicans</i> (Poison ivy)	1											1
<i>Rubus</i> sp. (Blackberry, etc.)	43			3	2		1			2		51
<i>Rumex</i> sp. (Dock)	27	13	2	17	22			2		50		134
<i>Sambucus canadensis</i> (Elderberry)	257											257
<i>Solanum rostratum</i> (Buffalo bur)	219											219
<i>Verbascum thapsus</i> (Mullen)	1	1										2
<i>Viola</i> sp. (Violet)	433		2	4	11	1	1	22		7	1	482
<i>Vitis</i> sp. (Grape)	48	4	1	6	1		3	1		5		69
Total	15792	577	117	153	165	15	24	108	3	182	7	17143

TABLE 6.4

Carbonized Plant Remains from Rodgers Shelter

Species	West Terrace						Main Excavation						
	1	2	3	4	5	6	1	2	3	4	5	6	7
<i>Chenopodium</i> sp.													
Lambsquarter	6						1	2	1				
<i>Solanum rostratum</i>													
Buffalo bur	2						3						
<i>Vitis</i> sp. Grape	5			1				1	(1)		(1)		
<i>Cereis canadensis</i>													
Redbud	17												
Cyperaceae Sedge	1												
<i>Croton</i> sp. Doveweed	1												
<i>Euphorbia</i> cf. <i>corollata</i>													
Spurge	4												
<i>Allium</i> sp. Bedstraw	6	1											
<i>Lespedeza</i> sp.													
Bush clover	1												
<i>Polygonum</i> sp. Knotweed	17	1											
<i>Rhus radicans</i>													
Poison ivy	1												
<i>Smilax</i> sp. Greenbriar	1												
<i>Acimina triloba</i>													
Paw paw							1						
<i>Cornus</i> cf. <i>drummondii</i>													
Dogwood									1				
<i>Diopyros virginiana</i>													
Persimmon									1		(1)		
Gramineae Grass									3				
<i>Helianthus</i> sp.													
Sunflower								1	2				
<i>Phytolacca americana</i>													
Pokeweed							5	2	1				
<i>Prunus</i> cf. <i>serotina</i>													
Black cherry													(1)
<i>Rosa</i> sp. Rose									1				
<i>Rubus</i> sp. Blackberry													
etc.								1					

fruit is present from August to November.

Greenbriar (*Smilax* sp.), a more or less herbaceous vine with edible rootstocks, young shoots and fruits. The fruits mature in the late summer.

Flowering spurge (*Euphorbia* cf. *corollata*), a plant of prairies, glades and open woods with poisonous sap. Seeds are present from June through October and are eaten by wild turkeys (Steyermark 1963:989).

Doveweed (*Croton* sp.), a common plant of the rocky glades above Rodgers Shelter, has poisonous sap and seeds which are eaten by turkeys

and quail. *M. monanthogynous* occurs on the slope above Rodgers Shelter, the seeds are present from June to October.

Bedstraw or cleavers (*Galium* sp.), common herbaceous forest plant, supposedly the greens are edible, the seeds can be used for a kind of coffee and the pleasant smelling foliage used for bedding. However, the plants are covered with curving, stiff hairs which would make eating them unpleasant. The seeds of some species, including those from Rodgers Shelter, are covered with bristles which causes them to stick to clothing. Seeds are present on the plant from May until they catch on something or until frost kills the plant.

Sedge (Cyperaceae family), grass-like plants producing seeds in late summer to fall. The tubers of one species, *Cyperus esculentus*, are edible in the spring and late fall (King 1976).

Bush clover (*Lespedeza* sp.), common herbaceous plants of prairies, open woods, glades, and thickets. Frequently grazed by white-tailed deer. The fruits are food for bobwhite, wild turkeys, etc.

Shelter and Main Excavation

The carbonized seeds which occur in the shelter area represent the following plants:

Blackberry, raspberry, or dewberry (*Rubus* sp.), numerous species are common in open woods and thickets, along bluffs, streams and in prairies. Fruit is available in one species or another from late May through July or August and can be dried and stored.

Dogwood (*Cornus* cf. *drummondi*), small tree occurring in dry or rocky woods, bottomlands, thickets and glades. The buds and twigs are sometimes eaten by deer, the fruit is eaten by birds.

Sunflower (*Helianthus* sp.), two carbonized seeds of a small seeded sunflower occur at Rodgers Shelter. There are numerous common species of sunflower that occur in disturbed areas, prairies, glades or thickets. The seeds of at least two species of sunflower found in the Truman Reservoir area were used by aborigines as food (*H. annus*, *H. maximiliani*). The carbonized sunflower achenes from Rodgers Shelter measure approximately 4.3 mm in length and are just slightly smaller than the minimum size for early cultivated sunflower (*H. annus*). It is possible that these achenes represent either a non-cultivated sunflower whose seeds were used as food, or else a weed growing at the site.

Pawpaw (*Asimina triloba*), bottomland tree producing edible fruit which are available in the fall (October). Pawpaws yield about 85 calories per 100 grams (Watts and Merrill 1963) and pawpaw trees grow in the bottomland in the vicinity of Rodgers Shelter today.

Pokeweed (*Phytolacca americana*), a perennial herb, the sprouts of which can be eaten in the early spring. The roots, grown stem, and berries are poisonous, although they have been used for medicinal purposes (Gilmore 1919).

Rose (*Rosa* sp.), fruits are available in the late summer and fall and can be used medicinally or made into a tea.

Hackberry (*Celtis* sp.), fruits are 1/4" to 1/2" in diameter with a thin flesh enclosing a hard, calcareous nutlet. They ripen in the fall and frequently hang on the tree most of the winter. They were sometimes used by the Indians who first ground them and then used them as a

seasoning or mixed with parched corn and fat (Yanovsky 1936). They were sometimes also thrown into a fire by the children to make a bang. Hackberry is one of the most common trees in the vicinity of Rodgers Shelter today. Many of the uncharred seeds in the upper horizons of the shelter have had a hole gnawed in them by a small rodent.

NUTS

Table 6.5 and Figures 6.2 and 6.3 show the occurrence of various types of carbonized nut remains at Rodgers Shelter. Figure 6.4 shows the variation in proportions of wood and nuts in various size fractions. This variation is much greater than that from the Zimmerman site (Asch and Asch 1975) and each size fraction had to be treated separately. In both the main excavation-shelter area and the west terrace, remains are plentiful only in the upper three horizons. Since both faunal and artifactual data indicate that the period of greatest occupation of the site was that represented by horizons 5 to 7, the scarcity of plant remains might best be ascribed to poor preservation.

Considering only the upper three horizons in which nuts and charcoal are relatively abundant, there is a considerable difference between the west terrace where there are virtually no carbonized nut remains and the main shelter area where they predominate. Nuts are available in the late summer (hazelnuts) to fall (hickory, walnuts, acorns) and indicate that the shelter was probably being occupied sometime during the fall or winter. The small number of acorn remains from the site may indicate the lack of their use or their relatively poor preservability because of their thinner shells. Carbonized nut shells are much denser and potentially more durable than wood charcoal. The lack of comparably durable carbonized nut shells on the west terrace suggests this area was probably occupied during seasons when nuts were not normally available or was occupied for only brief periods. The low volumes of carbonized wood or nut remains from the older horizons of the excavation, as well as the high proportion of wood in the material which is present suggests that prior to horizon 3 (approximately 3600 years ago) nuts may not have been an important food resource at Rodgers Shelter. Alternatively, they may have been treated in a manner non-conducive to preservation or prepared elsewhere on the site. Unlike the record of cultural material, we have plants from only a small portion of the site and cannot, on this basis, discuss their distribution over the site. It is also, therefore, impossible to determine what plant foods may have been processed at some other area of the site. Cultural materials suggest that during the period represented by horizons 5 and 6, occupation was in front of the overhang, while during horizons 1 through 4, it was more widespread across the terrace. This suggests that food processing may also have been in front of the overhang. However, it also suggests a difference in site utilization that might reflect a concomitant difference in season of usage or resource exploitation. The protection afforded by the shelter would most likely be utilized during the winter months. There is evidence that during the period of horizons 7 to 5, the site was a specialized hematite processing camp. Such "non-essential" activities might most readily be carried out during the fall-winter when hillslope vegetation was at a minimum.

TABLE 6.5

Carbonized Wood and Charcoal from Rodgers Shelter

WOOD					NUTS					WOOD					WOOD				
WOOD					NUTS					WOOD					WOOD				
WOOD					NUTS					WOOD					WOOD				
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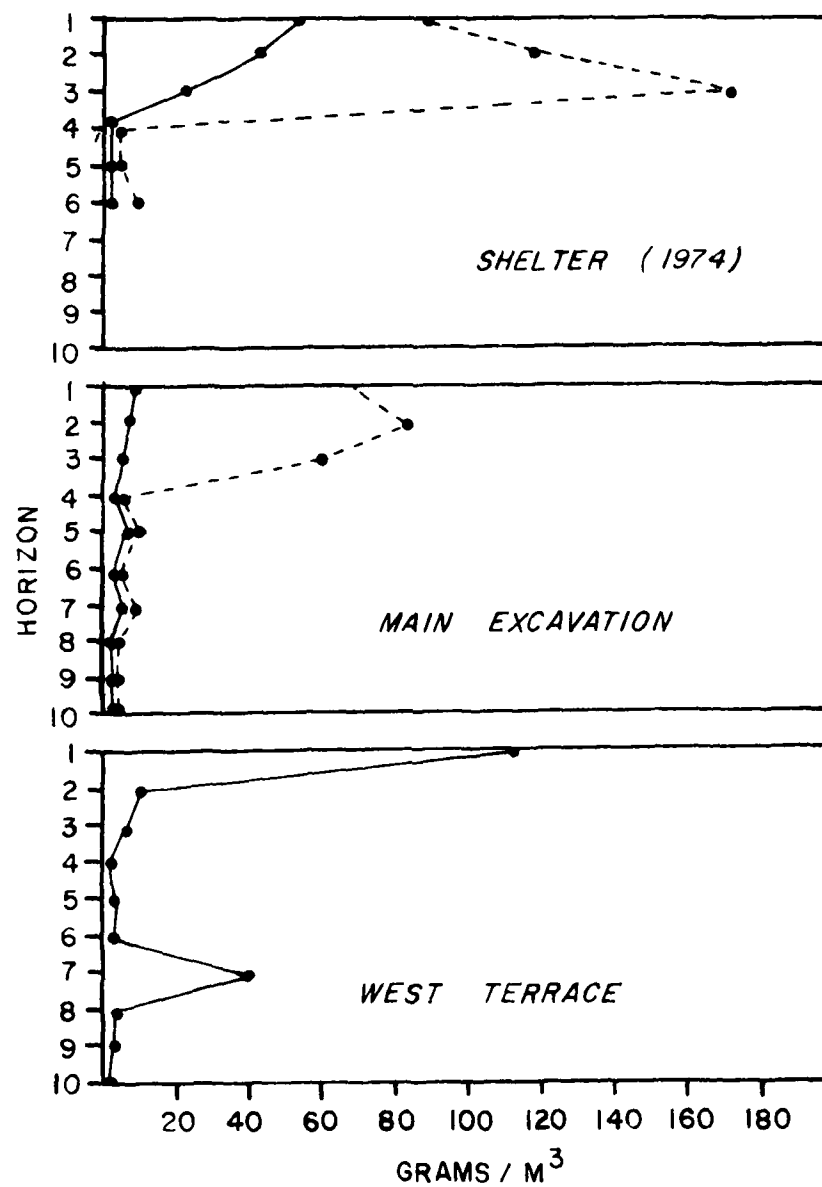


Figure 6.2. Volume of charcoal and carbonized nut shells, Rodgers Shelter.

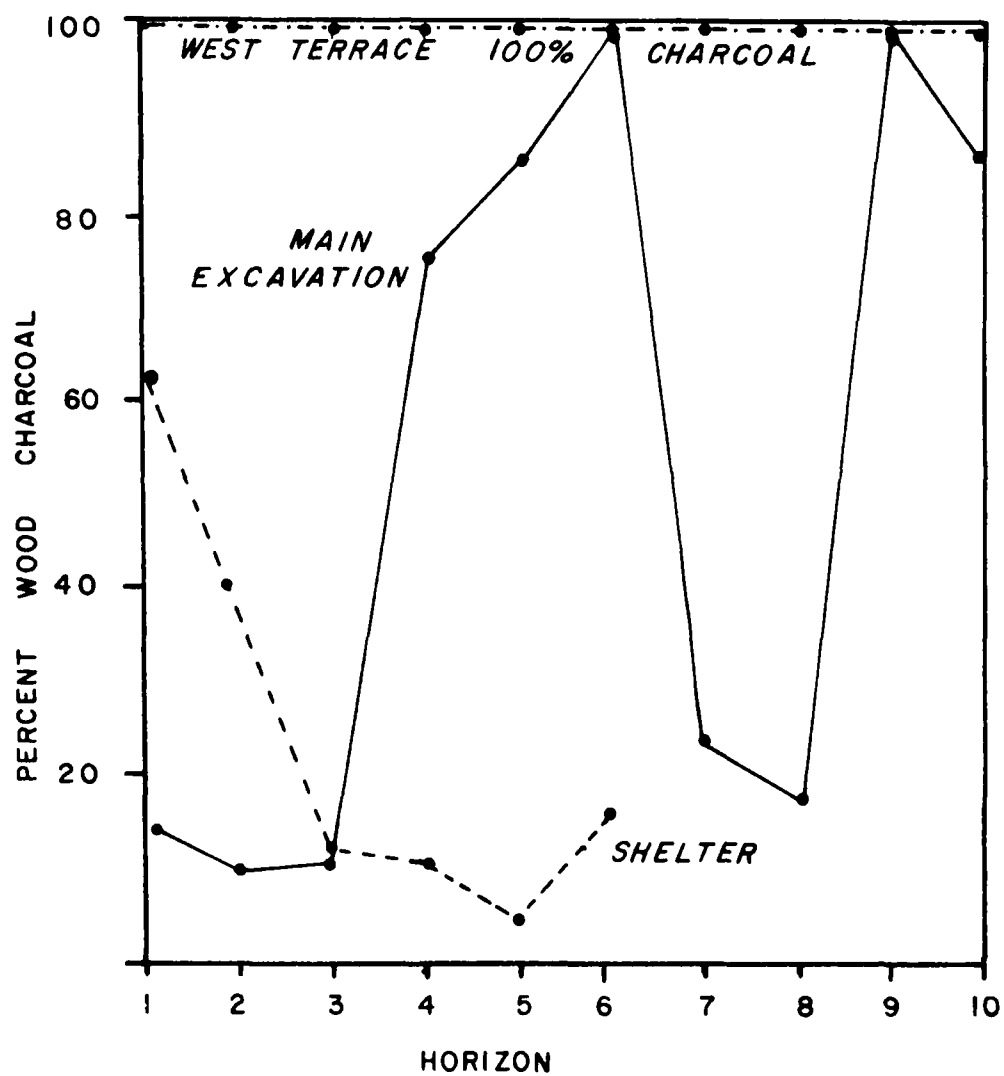


Figure 6.3. Comparison of relative percentages of wood charcoal from various excavation units at Rodgers Shelter.

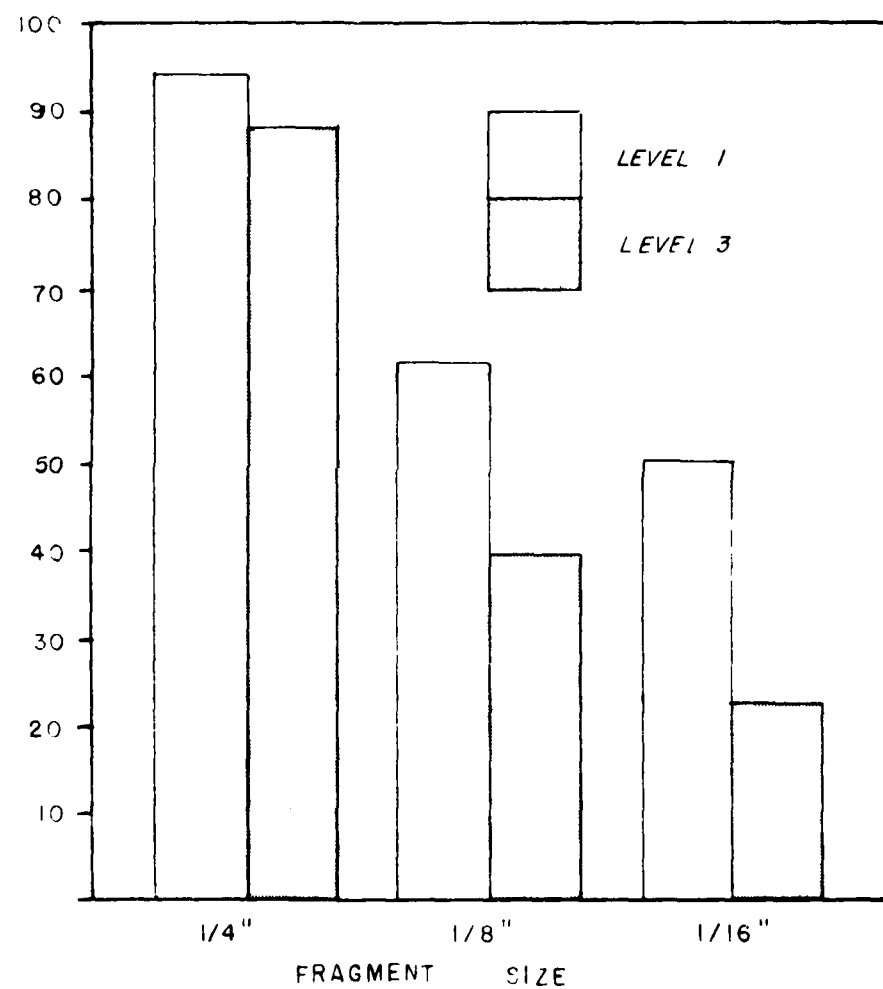


Figure 6.4. Examples of variation in proportion of wood versus nut shell fragments for various matrix size fractions for Rodgers Shelter, based on weights.

CHARCOAL

Identifiable charcoal from Rodgers Shelter includes both bottomland (ash, sycamore, maple, elm), upland/slope (red cedar) and types which might occur in either bottomland or upland situations (oak, hickory, osage orange) (Table 6.5). Charcoal from the west terrace includes these types as well as poplar or willow, basswood, and honey locust. Since charcoal preservation is poor, it is impossible to quantify or compare charcoal through time. However, horizons 5 to 7, which encompass much of the Middle Archaic cultural period as well as the warm, dry Hypsithermal climatic episode of the middle Holocene, wood types include oak, ash, sycamore, maple, and poplar/willow. These are all taxa present in the Ozarks area today as well as along stream channels as far west as eastern Kansas. Missing from these horizons are hickory, basswood, elm or hackberry, honey locust and juniper. However, the sample is too small to say with any degree of certainty that these were actually absent from the bottomland forest. The presence of oak, sycamore, maple, and red cedar in the lowest horizon from which charcoal was recovered, horizon 10, representing the Dalton period from about 10,500 to 9,500 years ago, suggests that at this time the arboreal vegetation in the area adjacent to Rodgers Shelter was, at least compositionally, similar to that of today, although the landscape and the distribution of these species on the floodplain and slopes may have changed. Osage orange is not native to Missouri and its presence in horizon 1 of the shelter probably represents contamination of this horizon by charcoal from recent fires which may have been built under the shelter.

COMPARISON WITH PRE-1974 DATA

The comparisons between the floral materials recovered from the 1974 and 1976 excavations at Rodgers Shelter and the earlier excavations must remain minimal because of the very different recovery techniques employed at different times. Parmalee *et al.* (1976:Table 9.1) shows the plant remains recovered prior to 1974. The small-scale debris from water screened samples produced approximately 1000 identifiable seeds and fragments of nuts from underneath the shelter, and produced various amounts of hickory nuts, walnuts, and acorns, although very little charcoal. The carbonized seeds recovered prior to 1974 include grape, persimmon and black cherry. As with the 1974 and 1976 materials, the presence of only relatively resistant carbonized nut shells and seeds suggests a poor preservation environment. The distribution of these carbonized remains throughout the cultural stratigraphic record at Rodgers Shelter suggests fall maturing plant foods were utilized to some degree during all occupation periods.

Although we must base use of nuts on the presence of carbonized remains in the archaeological record, the question of their initial carbonization remains. Gilmore (1919:74) states that the nuts were eaten plain or served with honey or made into soup. If put into a soup, the oil in the nut meats would float to the surface while the nut shells would sink to the bottom to be later discarded. The nuts of walnut (*Juglans regia*) contains about 35% oil and 40-45% protein while pecans (*Carya illinoensis*), a type of hickory nut, contains approximately 65%

oil and 12% protein (Vaughn 1970:115-116). It is obvious that nuts must have been pounded and put into food without removing any but the largest fragments of nut shells. For example, pieces of hickory nut shell up to 10 mm in diameter were recovered from human feces from Salts Cave (Yarnell 1969:44). In order for carbonized nut shells to appear in the archaeological record, we must assume that they were either processed near a hearth or discarded near one.

Chapman (1959) notes that walnuts, pecans, acorns, plums, pawpaws, persimmons, hog potatoes (*Amphicarpa bracteata*) and edible roots were an important part of the diet of the historic Osage Indians. Emphasis was placed on persimmons and lotus (*Nelumbo lutea*) because of their dependability. Lotus occurs in oxbow lakes, ponds in river floodplains. The Pomme de Terre River lacks suitable habitat and they are not found in the vicinity of Rodgers Shelter. Likewise, pecan is found only rarely along the Pomme de Terre. However, of the other taxa mentioned by Chapman as being important to the historic Osage, (excluding cultigens), all occur at Rodgers Shelter with the exception of hog peanut (potato). Both hog peanuts, which bear edible subterranean fruits and ground nuts of Pomme de Terre (*Apios americana*) occur in the area around Rodgers Shelter and although their remains do not appear in the archaeological record, possibly because of their perishability, they were probably of considerable importance to subsistence strategies focused on the shelter. Both hog peanuts and ground nuts are most easily gathered in the late fall or early spring (King 1976).

It may be concluded, on the basis of the available preserved floral remains from Rodgers Shelter, that at one time or another, most of the primary food plant resources in the area were exploited. These resources are nearly all available only in the fall. Inadequate sample size across the site, poor preservation of plant materials and the relative perishability of spring and summer plant foods make it impossible to determine on the basis of floral material whether the site was used in the spring or summer or whether there were temporal or spatial changes in site usage. These questions may be further answered through the analysis of animal remains and cultural debris.

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CHAPTER 7

THE HOLOCENE NAIAD RECORD AT RODGERS SHELTER IN THE WESTERN OZARK HIGHLAND OF MISSOURI

Walter E. Klippel, Gail Celmer, James R. Purdue

Freshwater mussels have contributed to the diets of prehistoric peoples throughout much of the known archaeological record in eastern North America. Where extensive Holocene records are present in stratified archaeological sites, there is a general trend of increased utilization of freshwater mussels as a food resource. Unmodified shells (i.e., refuse as opposed to tools and ornaments) are found in increasing abundance from Paleo-Indian/Early Archaic times (ca. 10,000 B.P.) at such sites as Modoc Rock Shelter (Early to Middle Archaic [Fowler 1959: 40]) in Illinois; Russell Cave (Clench 1974:86) in Alabama; Blackwell Cave (Falk 1969:83) and Graham Cave (Klippel 1971:84) in Missouri; and Sheep Rock Shelter (Willey and Ruskin 1968:164) in Pennsylvania.

Excavations of many Archaic Period open sites, especially those near medium to large sized rivers such as the Green River in Kentucky, Savannah River in Georgia and Tennessee River in Alabama and Tennessee indicate that extensive utilization of freshwater mussels ("Shell Mound Archaic") as a food resource began roughly 4000 to 5000 years ago (Marquandt and Watson 1977; Winters 1969:3). Some evidence suggests a slightly earlier date of between 6000 to 7000 B.P. (William and Stoltman 1965:670). Although this resource never became as important in the midwest and plains as it did in the southeast, increased occurrences of shellfish in many midwest and some plains sites (e.g., Collins 1972:91; Wedel 1961:87, 251) also began during the Middle Archaic Period.

A similar trend has been reported at Rodgers Shelter in the western Ozark Highland of southwestern Missouri (McMillan 1976:217). Considerable analyses of the archaeological remains and description of the biogeographical setting has been provided for the environment around Rodgers Shelter (Wood and McMillan 1976). We have continued work in this area by quantitative sampling of the extant naiads in the lower Pomme de Terre River near this archaeological site.

Although the naiad population in the Pomme de Terre has apparently undergone some recent changes as a result of modern human activities in the upper portion of the drainage, the Pomme de Terre River still supports a rich, diverse naiad fauna (McMillan 1976:41). In this respect, it differs from many other streams in eastern North America in that it has not been subject to the quantum changes reported for other streams brought about by Historic Period American occupation; e.g., in the Mississippi River near the Modoc Rock Shelter south of St. Louis where the naiad population has been all but extirpated (van der Schalie and van der Schalie 1950:449) or the Illinois River where naiad populations have been drastically altered (Starrett 1971:363).

NAIADS OF THE WESTERN OZARK HIGHLAND

Freshwater mussels in streams along the western Ozark Highland of Missouri have received little attention since the early work by Utterback (1915-1916) during the first quarter of the twentieth century. Aside from occasional references to mussels as they relate to archaeological studies (e.g., McMillan 1976:41; Parmalee and Klippel 1974:442) little is known about the naiad populations in the streams of the western Ozarks. The biological survey of the Spring River drainage reported by Branson (1966) represents a single exception.

During August, 1976, the Illinois State Museum Society supported five days of field work collecting mussels along the lower reaches of the Pomme de Terre River (Fig. 7.1). Collections and inventories were conducted in the river from four miles below the Pomme de Terre dam to roughly four miles south (upstream) from the confluence with the Osage River, a distance of approximately thirty-six miles. Thus, specimens were recovered both upstream and downstream from Rodgers Shelter.

The river was floated with canoes during low water and selective grab samples were collected. Generally, these samples consisted of fresh shells recovered from active muskrat piles that were frequently found in and along the water willows (*Dianthera americana*) that grow in considerable abundance in the shallow water. Fresh shells were also collected from shallow riffles and dry gravel bars.

Ten muskrat piles were completely collected and shells kept separate as discrete units (Stations 1, 2, 3, 4, 5, 6, 7, 8, 11, 12). All specimens from these stations were returned to the Illinois State Museum for processing, identification, and curating. On two occasions (Stations 1a and 5a) live mussels from water immediately adjacent to muskrat piles were also collected by excavating the mussels from three meter wide transects to a depth of 15 cm below the substrate surface. The transect at Station 1a was excavated two meters out into the stream (6 m²) in water ranging from 18 to 45 cm in depth while the transect at Station 5a (24 m²) extended across the river at a riffle ranging from 0 to 30 cm deep. The upper 15 cm of the latter transect was screened through 13 mm hardware cloth and mussels sorted from the gravel and other debitage. In both instances, all mussels were returned to the Illinois State Museum.

Mussels were also quantitatively collected from three other stations on the Pomme de Terre River. Stations 9 (120 m²) and 10 (25 m²) were located in slack water areas. Both areas were staked off in water 20 to 70 cm deep and systematically searched for naiads. The substrata of both slack water areas consisted of silts, clays and considerable decomposing vegetation (muck). Mussels were collected by hand sifting through the upper 15 to 20 cm of this substrata. At Station 9 all mussels were kept but at Station 10 only a small fraction was retained after identification and recording were completed.

The final station systematically collected (Station 13) was a shoal habitat just upstream from the riffle at Avery Bridge. A three-meter wide transect, 13 m long (39 m²) was collected across the river in fairly fast moving water ranging from 45 to 60 cm in depth. Collecting was again conducted by hand, carefully working through the pebbles, sand and silt to a substrata depth of 5 to 10 cm. After identification

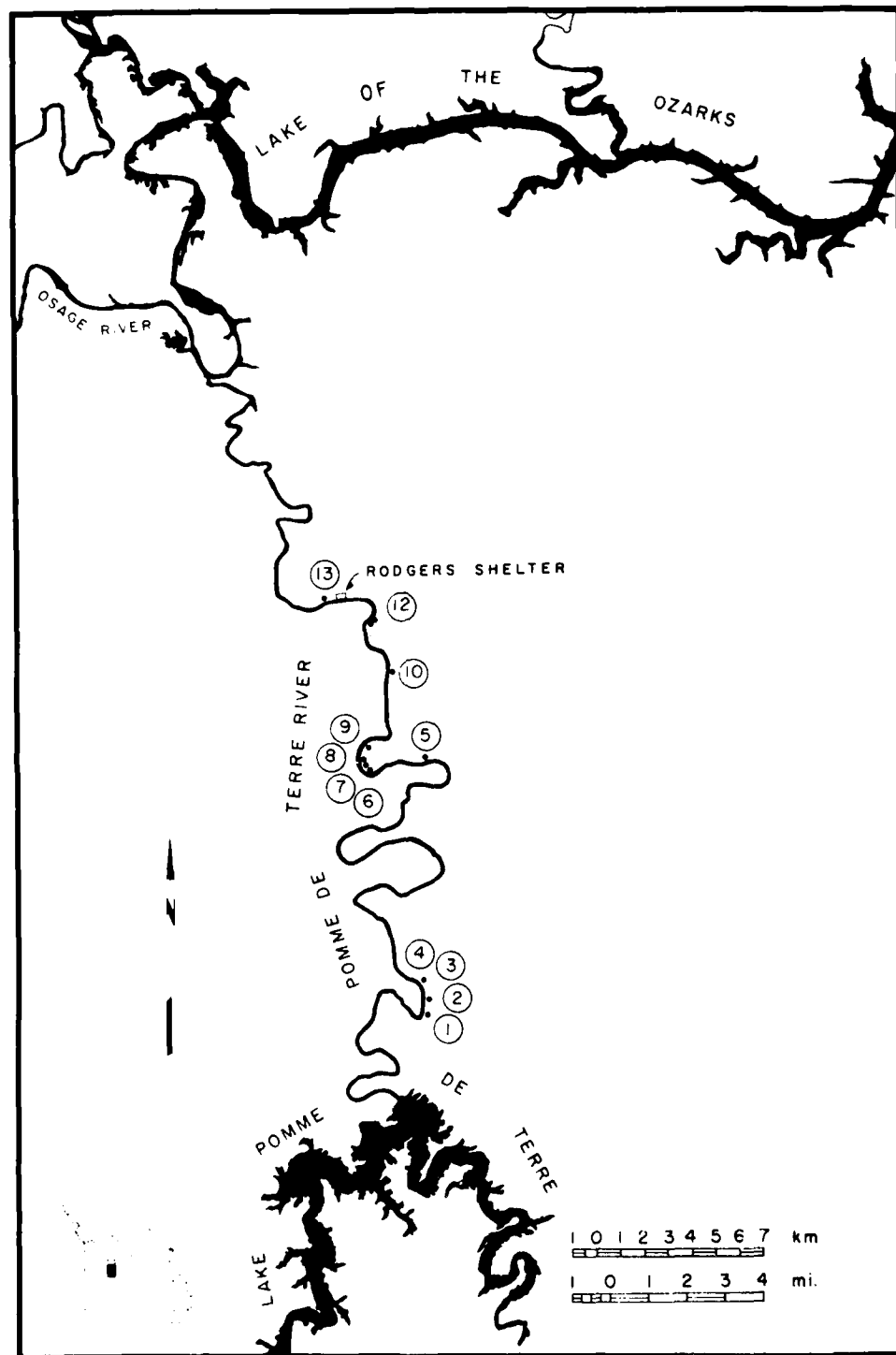


Figure 7.1. The lower Pomme de Terre River in southwest Missouri. Encircled numbers represent loci at which naiads were systematically collected during 1976.

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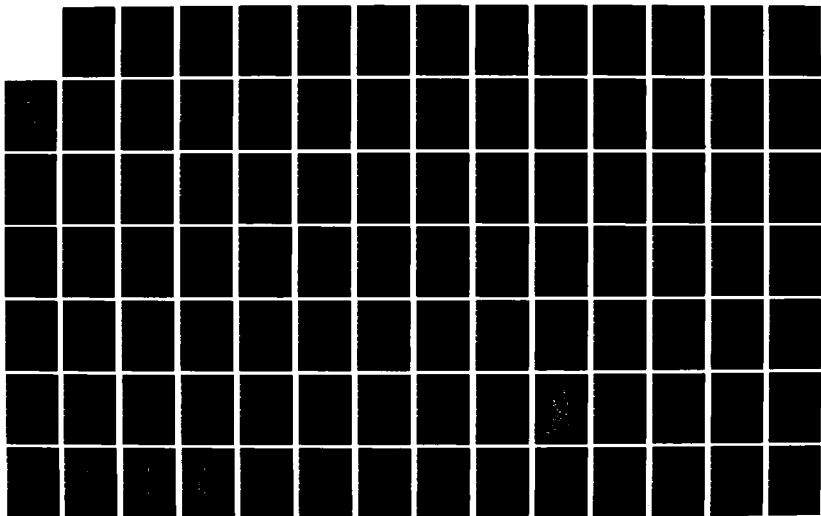
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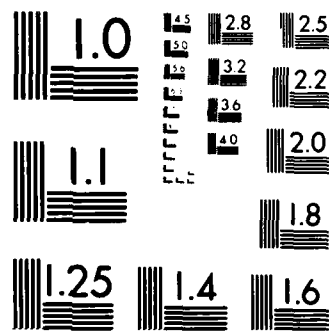
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most mussels were returned to the river bottom.

Species recovered from the various stations, as well as those represented in the grab sample are presented in Table 7.1. Although collections have not been extensive, those that have been made show considerable variation in species composition between habitats (e.g., riffles [Station 5a]; slack water [Stations 9 and 10]; and shoals [Station 13]). Differences in species represented between Stations 9 and 10 (both slack water) were assessed by computing a chi square ($\chi^2 = 6.6$, $df = 11$, $p = .80$) for respective populations. No significant difference was found at the 0.80 level and therefore samples have been combined.

Amblema plicata and *Quadrula pustulosa* were ubiquitous and occur in fairly large proportions (23 percent) with respect to the three different habitats samples (riffles, shoals, and slack water). However, other species vary widely. *Actinonaias ellipsiformis* and *Truncilla truncata*, each of which constitute more than three percent of the population from the riffle occur in complementary distributions with respect to the other two habitats samples (Table 7.1). Several additional species that occur in smaller frequencies also occur in mutually exclusive habitats, i.e., riffle: *Alasmodonta marginata*, *Lampsilis anodontoides*, *Leptodea fragilis*, *Quadrula metanevra*, *Quadrula quadrula*, *Strophitus undulatus* and *Truncilla donaciformis*; slack water: *Lampsilia fallaciosa*. In general, the riffle contained a larger number of species than either the slack water or shoal and the naiaid density per unit area on the riffle ($17.4/m^2$) was considerably higher than at either slack waters ($1.2/m^2$) or shoal ($4.2/m^2$).

Principal factoring, as defined by Nie *et al.* (1975), was used to examine patterns of variation in species composition of mussels from four situations (riffle, shoal, slack water, and muskrat pile) in the Pomme de Terre River. Additional information on factoring techniques can be found in a variety of texts (Cooley and Lohnes 1971; Morrison 1976; Davis 1973). As before habitat replicates, when present, were combined and relative species composition - as represented by the number of a particular species present in a category divided by the total number of individuals in that category ($\times 100$) - was calculated. Data were standardized further by the use of z-scores (Nie *et al.* 1975). Principal factoring without iteration was used to extract principal factors and factor scores. Separation on the first axis split muskrat piles from the other situations (Fig. 7.2). The species that contribute most to this separation are those with high correlations listed in Table 7.2. Those species with high negative scores are those preferentially taken by muskrats and mussels with high positive values are either avoided by muskrats, or, in some instances, perhaps not available for predation.

Riffles were split from the other three categories on principal factor II (Fig. 7.2). Species responsible for the separation, *Cyclonaias tuberculata*, *Elliptio dilatatus*, *Leptodea fragilis*, *Quadrula pustulosa*, *Q. quadrula*, and *Truncilla donaciformis*, all have high positive coefficients (Table 7.2). On axis III slack water and shoal habitats were split (Fig. 7.2) based on species with negative loadings (slack water) and those with positive coefficients (shoal). In Table

TABLE 7.1
Freshwater Mussels Recovered from the Lower Pomme de Terre River during 1976

Station Number	1	2	3	4	5	5a	6	7	8	9	10	11	12	13	Total	Grab Sample
<i>Actinonaias carinata</i>	1	2	-	-	1	42	5	1	23	1	1	9	12	27	90	X
<i>A. ellipsiformis</i>	7	-	4	1	18	32	34	-	24	-	-	17	12	-	176	X
<i>Alasmidonta marginata</i>	1	-	1	-	-	1	1	1	5	-	-	5	6	-	20	X
<i>Amblema plicata</i>	2	30	1	1	-	64	-	-	-	87	-	12	5	68	272	X
<i>Anondonta grandis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Arcidens confragosus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Cyclonaias tuberculata</i>	1	1	-	-	2	2	38	1	-	6	-	3	2	7	63	X
<i>Elliptio dilatatus</i>	2	3	-	1	3	60	-	1	-	-	-	1	1	7	78	X
<i>Fusconaia flava</i>	-	-	-	-	-	1	-	-	-	1	1	1	-	10	14	X
<i>Lampsilis anodontoides</i>	-	-	-	-	-	-	-	-	-	3	1	-	-	-	4	X
<i>L. fallaciosa</i>	1	-	-	-	-	1	-	-	-	1	2	-	-	-	5	X
<i>L. ventricosa</i>	-	2	-	-	1	16	-	1	4	2	2	2	2	8	42	X
<i>Lasmigona complanata</i>	-	-	-	-	-	1	-	-	-	3	2	-	-	-	6	X
<i>L. costata</i>	-	-	-	-	-	1	-	1	-	-	-	-	-	4	6	X
<i>Leptodea fragilis</i>	-	3	1	-	-	7	-	-	1	-	-	2	2	-	16	X
<i>Ligumia recta</i>	-	-	-	-	-	1	-	-	-	-	-	-	-	2	3	X
<i>Obliquaria reflexa</i>	13	5	7	4	15	6	1	1	4	1	4	14	11	-	81	X
<i>Plagiola lineolata</i>	2	-	2	-	-	2	2	1	2	1	1	4	3	1	18	X
<i>Pleurobema cordatum</i>	-	-	-	-	-	2	2	-	-	1	1	2	1	1	7	X
<i>Potamilus alatus</i>	-	6	-	-	-	6	-	-	-	16	8	1	1	17	55	X
<i>Quadrula metanevra</i>	-	-	-	-	-	1	-	-	-	-	-	5	11	-	6	X
<i>Q. pustulosa</i>	2	12	-	1	2	83	-	1	1	13	-	4	2	5	138	X
<i>Q. quadrula</i>	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	X
<i>Strophitus undulatus</i>	-	-	-	-	-	1	1	1	4	-	-	2	-	-	10	X
<i>Tritogonia verrucosa</i>	-	-	-	-	-	10	-	-	-	-	-	-	-	5	15	X
<i>Truncilla donaciformis</i>	1	3	-	-	-	7	-	-	-	-	-	1	-	-	12	X
<i>T. truncata</i>	59	2	16	16	30	17	33	-	4	-	-	-	83	-	298	X
Total	92	69	32	25	53	42	417	46	32	133	34	165	37	162	1436	

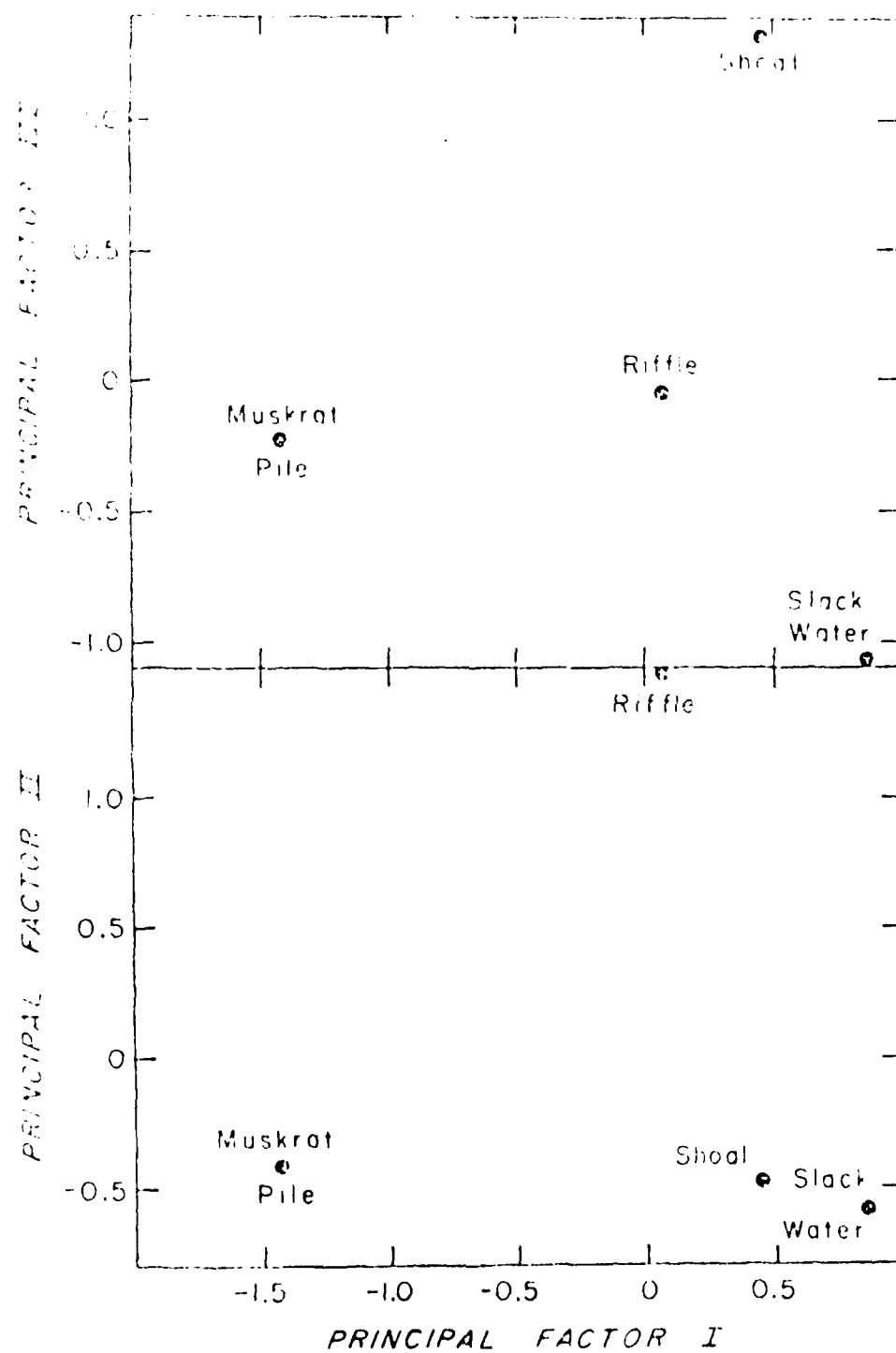


Figure 7.2. First three principal factor axes for modern species composition in the Pomme de Terre River.

TABLE 7.2

Factor Loadings and Other Data
for Pomme de Terre River Mussel Species Composition

Species	Principal Factors		
	I	II	III
<i>Actinonaias carinata</i>	0.30	0.14	0.95
<i>A. ellipsiformis</i>	-0.99	0.00	-0.17
<i>Alasmidonta marginata</i>	-0.95	-0.29	-0.15
<i>Amblema plicata</i>	0.94	-0.34	0.02
<i>Cyclonaias tuberculata</i>	0.10	0.89	0.44
<i>Elliptio dilatatus</i>	0.16	0.95	0.26
<i>Fusconaia flava</i>	0.54	-0.48	0.70
<i>Lampsilis anodontoides</i>	0.58	-0.39	-0.71
<i>L. fallaciosa</i>	0.58	-0.39	-0.71
<i>L. ventricosa</i>	0.92	0.19	0.33
<i>Lasimigona complanata</i>	0.58	-0.39	-0.71
<i>L. costata</i>	0.31	-0.32	0.89
<i>Leptodea fragilis</i>	-0.44	0.89	-0.11
<i>Ligumia recta</i>	0.31	-0.32	0.89
<i>Obliquaria reflexa</i>	-0.93	-0.20	-0.32
<i>Plagiola lineolata</i>	-0.61	-0.79	-0.07
<i>Pleurobema cordatum</i>	0.77	-0.57	-0.28
<i>Potamilus alatus</i>	0.87	-0.46	-0.19
<i>Quadrula metanevra</i>	-0.95	-0.29	-0.15
<i>Q. pustulosa</i>	0.34	0.86	-0.39
<i>Q. quadrula</i>	0.05	1.00	-0.03
<i>Strophitus undulatus</i>	-0.95	-0.29	-0.15
<i>Tritogonia verrucosa</i>	0.35	0.34	0.87
<i>Truncilla donaciformis</i>	0.05	1.00	-0.03
<i>T. truncata</i>	-0.98	-0.13	-0.16
Eigenvalue	11.31	8.32	5.38
Percent explained variation (unrotated factors)	45.20	33.30	21.50
Cummulative percent	45.20	78.50	100.00

7.2, *Actinonaias carinata*, *Fusconaia flava*, *Lasimigona costata*, *Ligumia recta*, and *Tritogonia verrucosa* have positive values and, therefore, indicate they were found in higher proportions in shoal habitats. The reverse relationship was apparent for *Lampsilis anodontoides*, *L. fallaciosa*, *Lasimigona complanata*, and *Quadrula pustulosa*.

SHELLFISH AND SUBSISTENCE AT RODGERS SHELTER

Previous analyses of faunal remains from Rodgers Shelter have suggested that there were marked changes in the utilization of mussels throughout the Holocene Period at the site (McMillan 1976:217). However, because of the difficulties of comparing shellfish remains with other faunal resources, mussels from the site have been largely ignored. McMillan (1976:216), however, did compare frequencies of individual identifiable valves with frequencies of individual identifiable vertebrate elements as they changed through time. The result of his analysis clearly suggests that mussel utilization increased through time (Table 7.3, after McMillan 1976:217).

TABLE 7.3

Distribution of Identifiable Mussel Valves
and Identifiable Vertebrate Elements*

Years Before Present	Culture/ Time Units*	Percent Identifiable Mussel Valves	Percent Identifiable Vertebrate Elements	Total Mussel Valves and Vertebrate Elements
1000-1750	1	94	6	1041
1750-2500	2	93	7	1810
2500-3600	3	97	3	1252
3600-5200	4	99	1	479
5200-6700	5	69	31	769
6700-7500	6	26	74	937
7500-8100	7	9	91	1190
	8	3	97	378
8100-8600	9	1	99	388
8600-9500	10	0	100	8
9500-10,500	11	17	83	150
10,500-11,000	12	0	100	9

*Naiad data were analyzed prior to completion of the stratigraphic revision presented in Chapter 4. Consequently temporally corrected culture/time units of McMillan (1976:217) are retained. Results differ only slightly in detail and overall conclusions are unaffected by retention of culture/time units.

Using these same specimens, we have attempted to assess some of the ramifications of this observation. Specimens have been identified to species when possible. Identifications were only attempted on those valves with pseudocardinal and lateral teeth intact except for edentulous species; however, because of the deteriorated condition of the shells, it was only possible to identify many of the valves to genus (Table 7.4).

Minimum number of mussels were calculated for each culture/time unit (Table 7.4) by considering right vs. left valves. The fragmentary

TABLE 7.4
Freshwater Mussels Recovered from Rodgers Shelter 1963-1968

Culture/Time Stratigraphic Units													Total
1	62	30	39	-	29	13	11	26	8	8	4	1	324
2	83	48	67	4	70	14	20	53	12	18	11	12	611
3	35	43	49	3	35	6	17	45	5	5	11	4	391
4	21	42	-	-	12	1	3	54	17	-	1	1	185
5	4	18	19	-	7	2	4	19	12	1	2	4	96
6	2	11	5	-	4	-	-	9	6	1	-	1	43
7	3	17	12	-	11	1	3	16	17	2	3	1	102
7/8	-	2	1	-	3	-	-	2	1	1	1	-	13
8	2	8	1	1	1	-	-	2	3	-	-	1	20
9	-	-	-	-	1	-	-	-	-	-	-	-	1
11	1	-	-	-	1	-	-	3	-	-	-	-	6
Total	213	219	193	8	174	37	58	398	180	30	37	19	1792

condition of the shells precluded increasing minimum numbers by using size criteria in combination with right vs. left valves.

Having converted numbers of mussel valves to minimum number of animals by genera and species we now assess freshwater mussels as a prehistoric food resource in the subsistence economy of prehistoric inhabitants at Rodgers Shelter. As usual, converting numbers of valves to minimum number of animals greatly reduced the sample of mussels. Further evaluation can be made by converting numbers of animals to meat weight per species. Parmalee and Klippel (1974) have reported weights by species for all of the mussels that have been identified from Rodgers Shelter. If we assume that all mussels from the site were large for their species (i.e., on the high end of the observed range reported by Parmalee and Klippel, 1974) the total amount of meat provided by the mussels from the site would amount to less than 54 kg (120 lb.). If this figure is converted to food energy (calories) and compared to other species of animals recovered from the site such as white-tailed deer (*Odocoileus virginianus*), we find that food energy provided by the total number of mussels from the site amounts to less than would have been provided by two white-tailed deer (White 1953:397; Parmalee and Klippel 1974:431).

Thus, while a comparison of numbers of valves and numbers of vertebrate elements (Table 7.3) provides the impression that freshwater mussels may have been of considerable importance in the subsistence economy of Late Archaic and Woodland period inhabitants, when food energy is used as a measure, it is apparent that shellfish contributed little in the way of food energy to the subsistence economies of the inhabitants of Rodgers Shelter. Not only is this resource relatively low in food energy per unit weight compared to most other animals, prehistoric inhabitants of the site do not seem to have been exploiting it to any appreciable extent. If, for example, we assume that present day naiad populations roughly approximate prehistoric populations, the minimum number of mussels recovered from Rodgers Shelter do not exceed the number of shellfish that one might expect to recover from 100 m² on a riffle, such as that collected at Station 5a (Table 7.1). Even a small stretch of shoal, 10 x 40 m (i.e., 400 m²) like that collected at Station 13 would produce more naiad biomass at one point in time than has been recovered through the extensive excavations at Rodgers Shelter. Presented another way, shellfish per decade by horizon at Rodgers Shelter can be summarized as follows: Horizon 1 (4.3); 2 (8.1); 3 (7.8); 4 (0.1); 5 (2.4); 6 (1.4); 7 (1.0); 8 through 12 (0.1).

Although shellfish do not seem to have contributed any appreciable portion to the subsistence of the prehistoric inhabitants of Rodgers Shelter, what of their general increased utilization through time? Speculation about the dramatic increase in exploitation during the Middle to Late Archaic in the southeast and midwest has been variously attributed to increased availability of this class of animal. Lewis and Lewis (1961:20), for example, indicate that climate change provided a more suitable aquatic environment while Winters (1969:5) suggests that abating isostatic rebound and phenomena related to reduced downcutting of streams provided the requisite conditions for larger mussel populations.

Testing the hypothesis that shellfish became more numerous in eastern North America is difficult at this point. However, even if

mussels did become more numerous after roughly 7000 years ago, we cannot preclude the notion that the increased utilization of shellfish could also have resulted from human population pressure (Cohen 1975:473; Evans 1969:480) and their late acceptance is merely a manifestation of the "Late Diffuse" adaptation in eastern North America (Cleland 1976:71), a concept similar to the "broad spectrum revolution" delineated by Flannery (1969:77-79).

Increased utilization of aquatic resources in general have been attributed to population pressure (Cohen 1975:473; Horner 1970:71). And, although the sample of vertebrates recovered from Rodgers Shelter is small, it is interesting to note that, by comparison, identifiable aquatic vertebrate elements (as well as shellfish) increase in relation to terrestrial vertebrates during the late Middle Archaic (Middle Archaic II [McMillan 1976:214]) and are proportionately more numerous during the Late Archaic and Woodland periods than during the Early Archaic and Early Middle Archaic (i.e., Middle Archaic I).

VARIATION IN NAIAD ASSEMBLAGES FROM RODGERS SHELTER

We have noted previously that present day mussel population in the Pomme de Terre River is in marked contrast to many other midwestern streams whose naiad fauna have been greatly reduced if not completely extirpated. If one compares the species collected from the lower Pomme de Terre River during 1976 (Table 7.1) with those identified from Rodgers Shelter (Table 7.4) it is apparent that as many as eleven species are extant in the fluvial system today that were not identified from Rodgers Shelter. The large majority of these occur in very low frequencies in the Pomme de Terre today -- i.e., *Arcidens confragosus*, *Lampsilis anodontoides*, *Lampsilis fallaciosa*, *Lasmigona complanata*, *Quadrula melanevra*, *Quadrula quadrula* -- and/or are very thin-shelled or small and may not have preserved well in the deposits at Rodgers Shelter -- i.e., *Anodonta grandis*, *Leptodea fragilis*, and *Truncilla donaciformis*. Only two thick-shelled species occur in relatively large numbers today that were not recovered from Rodgers Shelter (i.e., *Obliquaria reflexa*, and *Plagiola lineolata*, both of which are easily identifiable even when the periostracum is eroded away).

Variation in species occurrence at Rodgers Shelter by horizon seems, in large part, to be influenced by the relatively small number of mussels in some units (Table 7.4); i.e., those units with few species generally have less diverse species assemblages. As a result, we have collapsed horizons 7/8 through 11 (Early and Early Middle Archaic) into one unit (8, N = 40) to facilitate further comparison. Also, because recent collections (described above) were all made in relatively shallow water (i.e., 75 cm) and would probably have been those same environments most accessible to prehistoric peoples (as opposed to deep pools, for example) we have combined modern populations also.

The patterns of explainable variation in species composition resulting from combining modern Pomme de Terre River and Rodgers Shelter mussels were examined using principal factoring. Data were relativized and standardized using the technique previously described. When relative frequencies were calculated, eight of the modern species collected in

the Pomme de Terre rounded to zero. These species were deleted from the analysis. Principal factoring without iteration was again applied for the extraction of principal factors and factor scores.

Separation on the first factor clearly split modern from prehistoric mussels (Figure 7.3). Species with high loadings on Factor I (Table 7.5) are those with increased proportions in the modern sample. Species like *Leptodea fragilis*, *Truncilla donaciformis*, and *T. truncata* may well occur in low frequency because of differences in preservation while other species (e.g., *Amblema plicata*, *Proptera alata*, *Quadrula pustulosa* and *Obliquaria reflexa*) do not seem to be as adversely affected by perturbation of recent Euro-Americans as many other species (e.g., see Starrett 1971:341). Two species, *Elliptio dilatatus* and *Fusconaia flava* were proportionately more common in the prehistoric collection. Both species appear to be fairly sensitive to pollution and, unlike those species with high loadings, have been extirpated from the Illinois River (Starrett 1971:340).

TABLE 7.5

Principal Components Data on Combined Modern Pomme de Terre River and Rodgers Shelter Mussel Species Composition

Species	Factor Score Coefficients		
	I	II	III
<i>Actinonaias carinata</i>	-0.29	0.90	-0.07
<i>A. ellipsiformis</i>	-0.35	-0.80	-0.01
<i>Alasmidonta marginata</i>	0.01	-0.07	0.55
<i>Amblema plicata</i>	0.53	-0.06	0.78
<i>Cyclonaias tuberculata</i>	0.33	0.83	0.11
<i>Elliptio dilatatus</i>	-0.81	0.07	-0.51
<i>Fusconaia flava</i>	-0.71	-0.46	0.01
<i>Lampsilis ventricosa</i>	0.18	0.07	0.80
<i>Leptodea fragilis</i>	0.98	0.05	0.18
<i>Obliquaria reflexa</i>	0.98	0.05	0.18
<i>Plagiola lineolata</i>	0.98	0.05	0.18
<i>Potamilus alatus</i>	0.93	0.24	0.21
<i>Quadrula pustulosa</i>	0.84	-0.09	-0.37
<i>Strophitus undulatus</i>	-0.09	0.38	0.01
<i>Tritogonia verrucosa</i>	-0.10	0.41	0.35
<i>Truncilla donaciformis</i>	0.98	0.05	0.18
<i>T. truncata</i>	0.87	0.16	0.18
Eigenvalues	8.63	2.88	2.61
Percent explained variation (unrotated factors)	50.80	16.90	15.30
Cumulative percent	50.80	67.70	83.00

Principal axis II is interesting because it indicates a time series with the prehistoric mussels (Figure 7.3). *Actinonaias carinata* and

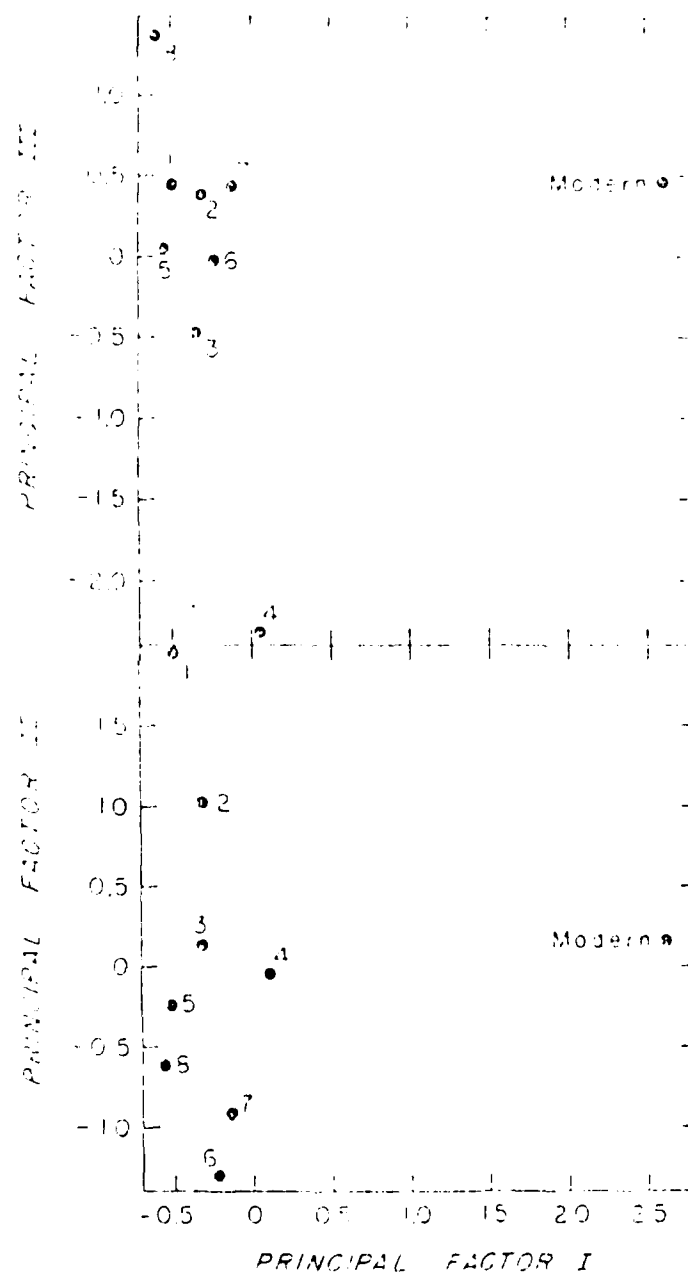


Figure 7.3. First three principal factor axes for lumped modern and stratigraphically controlled prehistoric mussel species composition.

Lysenaias tuberculata have high positive correlation with axis II while a congener of *A. carinata*, *A. ellipsiformis* is strongly negative (Table 7.5). In our modern collections *A. carinata* and *C. tuberculata* were recovered in relatively large proportions from both shoals and riffles while *A. ellipsiformis* was restricted to shallow riffles. Parmalee (1967:57) has described the ecology of *A. carinata* in Illinois as "...characteristic primarily of medium sized and larger rivers, although it may become established locally in deeper portions of smaller rivers..." *C. tuberculata* occurs in both small streams and large rivers in shallow (ca. 30 cm) to deep (3 m) water (Parmalee 1967:27), while *A. ellipsiformis* "...typically inhabit streams and small rivers..." on riffles normally at depths of less than 30 cm (Parmalee 1967:57).

Although we are not prepared to discuss the many variables pursuant to a full explanation of why these three species may have varied in abundance in the prehistoric Pomme de Terre River, it is interesting to note that there is a general trend through time of decreased *A. ellipsiformis* (shallow water--small river) while *A. carinata* and *C. tuberculata* (shallow to deep water--small/medium to large river) increase. In those horizons with more than one specimen/decade, there is a steady trend toward larger river forms with respect to principal axis II.

Other data suggest that, in fact, moisture may have generally been more plentiful during the Late Archaic and Woodland periods than during the Middle Archaic in the western Ozark Highland (McMillan 1976: 228). If this observed trend is correct, the Pomme de Terre River may have taken on characteristics more typical of medium to large rivers during the Late Archaic/Woodland periods when compared to the Middle Archaic Period.

The third axis is not easily interpreted in that horizons 4 and 8 separate from the otherwise clustered prehistoric units. Both units 4 and 8 differ from the other units in that mussels occur in extremely low frequencies per given time span (i.e., about one naiad per century). We have suggested above that mussels were only infrequently utilized during the Paleo-Indian and Early Archaic periods and McMillan (1976: 230) has noted that Rodgers Shelter was all but abandoned at the time Stratum 3 (horizon 4) was aggrading.

In addition to the factor analysis just discussed, we have also attempted to look at the change in specific naiads that occur through the deposits at Rodgers Shelter. Unfortunately, because of the deteriorated condition of the majority of the specimens from the site, it is not possible to conduct growth analyses such as have been undertaken on modern species (e.g., Stein 1973) and well preserved specimens from other archaeological sites such as Koster in Illinois (Hill 1975). However, because Matteson (1960:120) has observed that mussels from Early and Middle Archaic context are dwarfed, Parmalee (1968:106) has suggested that prehistoric mussels from Modoc Rock Shelter are generally smaller than their modern counterparts and Hill (1975) has shown that *Amblema plicata* from the Middle Archaic units at Koster are generally smaller than modern specimens collected from the Illinois River, we have attempted to assess this observed phenomenon at Rodgers Shelter. *Amblema plicata* has been chosen because of its wide geographic distri-

bution permitting comparison with specimens from other loci and because it occurs in relatively large numbers throughout the deposits at Rodgers Shelter.

In order to assess size changes in the fragmented *A. plicata* from Rodgers Shelter, we have developed a "scale" based on modern specimens from the Pomme de Terre River. Modern specimens were measured and those that were an even multiple of 10 mm in length were selected from the large grab sample of *A. plicata* from the lower Pomme de Terre River. *A. plicata* with lengths of 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, and 130 (± 1 mm) were used as a scale and each perhistoric specimen placed into one of ten length classes (e.g., 60-70 mm) by comparing the fragmented archaeological specimens with eroded anterior, posterior, or ventral margins to intact modern specimens. By estimating sizes in this manner, it was possible to increase the known minimum number of *A. plicata* from 174 as shown in Table 7.4 to a minimum number of 187 (i.e., including unequal left vs. right valves in each size class).

The sixty-four *A. plicata* collected from Station 5a (Table 7.1) were also measured and placed in these same ten mm interval classes. A comparison of the modern population from Station 5a and those recovered from Rodgers Shelter (Fig. 7.4) clearly shows the mode of the modern population falls in a size class considerably larger than the prehistoric population. The median for the modern population (100-110 mm) is also considerably larger than the prehistoric population (60-70 mm). Thus, we can conclude that the observation put forth by Matteson (1960), Parmalee (1967) and Hill (1975) is generally replicated in *A. plicata* at Rodgers Shelter.

We have also plotted the size distribution of *A. plicata* by horizon at Rodgers Shelter (Table 7.6) and found that with the exception of five valves in Early Archaic and early Middle Archaic context; i.e., horizon 7 and below, that this species was generally smaller (80 mm long) throughout most of the Archaic than during the Late Archaic and Woodland periods, and appreciably smaller than those specimens of the same species collected during 1976.

From this admittedly rather crude measure, we can assume that either the prehistoric inhabitants of Rodgers Shelter were purposefully selecting small *A. plicata* during much of the Middle Archaic Period, but were less size-selective during the Late Archaic and Woodland periods, or that conditions in the Pomme de Terre River varied sufficiently through time that conditions conducive to larger *A. plicata* growth increased from the Middle Archaic, through the Woodland, and into the Historic Period.

Although we cannot prove that changes in size preference of *A. plicata* did not occur among the various prehistoric inhabitants of Rodgers Shelter, it is interesting to note that McMillan (1976:228) has postulated relatively dry conditions for southwestern Missouri during the Middle Archaic Period and Matteson (1955:141) has suggested that *A. plicata* are frequently dwarfed in Midwestern streams with slow moving water. A similar phenomenon has been observed among *A. plicata* from lake environments with little current, i.e., this mussel grows more slowly during their fast growth years (0-6 years), and are generally smaller as adults (Stein 1973:126). It can also be reiterated

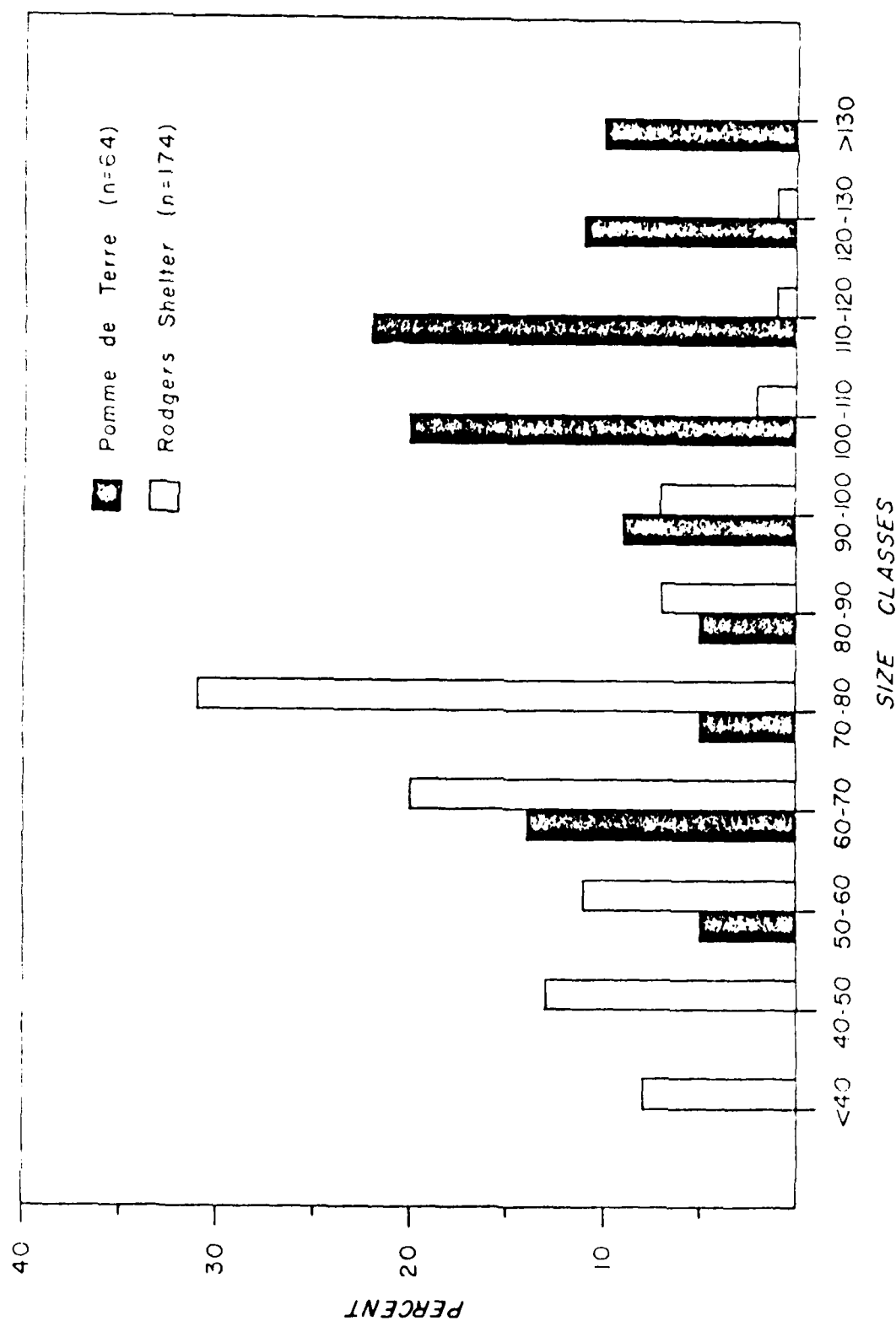


Figure 7.4. Histogram illustrating the variation in size of *Amblyma plicata* from Rodgers Shelter and live specimens collected from the Pomme de Terre River during 1976.

TABLE 7.6

Size Classes (length in mm) of *Amblema plicata*
from the Pomme de Terre River and Rodgers Shelter

Provenience	30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-130	130	Median
Modern sample*													
T/S unit 1†		1	2	3	9	3	3	6	13	14	7	6	96.92
T/S unit 2		3	8	7	13	21	5	3	1				74.58
T/S unit 3		3	7	5	10	13	6	7	2	1	1		71.67
T/S unit 4	1	3	3	1	4	3	1	1					65.00
T/S unit 5		1	2	2	1	2							55.00
T/S unit 6		1	1	1	1	1							52.50
T/S unit 7		1	2	2	1	3	2	1	1				50.00
T/S unit 8-12					3	3		1					71.67

*Modern sample collected from Station 5a during 1976.

†Time/stratigraphic units delineated by Wood and McMillan (1976).

that principal axis II of the above analysis indicated that the Pomme de Terre may have become a larger stream during the Late Archaic and Woodland periods than it was during the Middle Archaic Period which tends to support the supposition that the observed variation in size of *A. plicata* at Rodgers Shelter is a reflection of changes in aquatic habitat rather than a cultural selection.

SUMMARY

Shells of freshwater mussels are frequently observed in archaeological context and are sometimes mentioned in archaeological reports. However, they are only infrequently described, or treated in as much detail as are most other prehistoric human subsistence resources. Much of the problem seems to stem from a lack of quantitative information concerning the distribution of freshwater mussels in the streams and rivers of eastern North America today. But, even though modern naiad populations have been greatly altered as a result of recent human activity such as releasing large quantities of silt, toxic chemicals and other foreign matter into our fluvial systems, some streams still show considerable patterning in distributions of modern populations. We submit that systematic collecting and the use of multivariate statistics can be employed to describe the patterning that still exists in many naiad rich streams like the Pomme de Terre River and that these results can, with appropriate restraints, eventually be used to better understand the natural environment with which prehistoric human groups were articulating.

Mussel populations from various shallow water habitats within the Pomme de Terre River and mussel shells from muskrat piles along the banks have been identified, analyzed, and found to vary widely. Species composition of muskrat piles along the Pomme de Terre differed from live populations suggesting not only that muskrats were selective in the mussels they brought to the bank but more importantly, that these easily collected specimens are not necessarily representative of the extant populations in the river. Mussels from riffles, shoals, and slack waters also differed from each other in overall compositions with some species seeming to be ubiquitous while others were fairly restricted.

Although mussel shells recovered from some midwestern archaeological sites such as Rodgers Shelter are badly eroded, it is frequently possible to identify many of these valves to the species level and even to delineate patterned variation in size of specific species. Identification of the mussels deposited over eight to ten thousand years at Rodgers Shelter suggests that the naiad population in the Pomme de Terre River is as diverse today as it was in the past.

We have also observed, as was reported by McMillan (1976:217), that the use of freshwater mussels as a food resource increased throughout the Archaic Period, reaching seemingly significant proportions by the Late Archaic and Woodland periods. However, this importance is greatly reduced when numbers of valves are converted to food energy and compared to other identifiable resources from the site. The general increase in mussel exploitation has been tentatively attributed to increased population pressure among hunters and gatherers in this portion of the

western Ozark Highland.

A principal factoring of the modern naiad fauna from the Pomme de Terre River and those recovered from the various horizons at Rodgers Shelter has shown that the modern population differs markedly from the populations recovered from archaeological context, largely because of the lack of preservation among thin-shelled and very small species and the acceptance of certain species to recent human perturbations of the aquatic environment. Observed change in mussel species through time (axis II [Fig. 7.3]) has been attributed to increased amounts of water in the Pomme de Terre River which generally agrees with the observation put forth by McMillan (1976:228) that conditions were much drier during the Middle Archaic Period than during the Late Archaic and Woodland periods in the western Ozark Highland. The general increase in size from Middle Archaic through the Woodland period in *Amblema plicata* has been attributed to the same phenomenon.

The naiads recovered from Rodgers Shelter undoubtedly reflect other changes in the natural environment that we do not recognize at this point because of a lack of quantitative information on mussel populations in the streams of the western Ozark Highland and qualitative statements concerning their habitat. Further attempts should be made to refine the preliminary observations we have been able to make concerning modern naiad populations and their distribution in the Pomme de Terre River. And, additional mussel assemblages from archaeological contexts should be analyzed to determine if the patterning seen at Rodgers Shelter is replicated at other sites along the Pomme de Terre River.

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CHAPTER 8

HABITAT AND CLIMATIC INTERPRETATION FROM TERRESTRIAL GASTROPODS AT RODGERS SHELTER

David A. Baerreis and James Theler

Although the gastropod fauna of the State of Missouri is reasonably well known, older studies (e.g., Pilsbry and Ferris 1906; Sampson 1913) that are still the most comprehensive available stressed recording the distribution of individual species usually within the bounds of a political unit of county size. Thus, in attempting to make use of the gastropods from Rodgers Shelter to provide information on environmental conditions, it has been necessary to make additional collections of the modern fauna of the region to illuminate the character of faunal assemblages and the environmental conditions under which particular species flourish. It has also been essential to secure a population of modern snails to aid in the interpretation of morphological changes that may have occurred within a given species over time. The prehistoric gastropods were secured both from a stratigraphic column in square 241NW75 which was removed in .25 ft. levels and processed by flotation and water-screening using a brass screen with a mesh size of 0.4 mm in the laboratory at the University of Wisconsin-Madison and from the more extensive soil samples processed in the field. Material from these three separate sources--modern litter samples, laboratory flotation and field flotation--are tabulated and presented separately. While the latter two sources provide somewhat redundant data, separate tabulation permits an evaluation of potential variation introduced by processing technique.

MODERN GASTROPODS

Several transects were made to collect leaf litter samples from bottomlands to higher elevations. The procedure followed A. P. Jacot (1935) in using a steel cylinder made of eight-inch pipe to isolate three samples collected in close proximity in visually identical leaf litter. The grouped samples are presented in order of collection in Table 8.1. Sample No. 1 is from the limestone hillside above the shelter about twenty feet from the bluff edge. Samples 2, 3, and 4 are from successively higher elevations at this lower sector of the rocky hillside. Sample No. 5 is from the floodplain about midway between the two excavation units while No. 6 is from the base of the bluff in a position equivalent to the elevation of the modern shelter surface. Samples 7 through 11 are from higher elevations than any of the preceding samples and reflect a drier habitat. Sample 12 began another series of samples starting in a moist lowland habitat on the Pomme de Terre River south of Prairie Creek. Samples 13 and 14 are from forested floodplain conditions. Number 15 is from a slightly higher elevation at the foot of the limestone bluff. Sample 16 is from the hillslope above the bluff margin. Samples 17 through 19 were from near Phillips Spring and a dry habitat despite a lowland location. The final sample, No. 20, is from the Mora Prairie in a grassy area in north Benton County.

TABLE 8.1
Modern Gastropods from Litter Samples Collected near Rodgers Shelter

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
<i>Carychium eripuum</i> (Say)	0	0	0	11	42	65	0	0	0	0	0	168	27	257	174	8	0	0	0	0
<i>Polygona diffeutilima</i> Lea	0	3	1	14	0	6	0	0	0	0	0	0	0	0	1	1	1	0	0	0
<i>Stenotrema</i> sp.	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
<i>Mesodon elevatus</i> (Say)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
<i>M. inflectus</i> (Say)	0	0	0	8	0	5	1	2	0	1	0	0	0	0	5	3	1	0	0	0
<i>M. thyriscus</i> (Say)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
<i>Mesodon</i> sp.	1	0	0	0	1	4	0	0	0	1	0	1	0	0	0	0	0	0	0	0
<i>Eucnulus</i> sp.	0	0	1	4	0	0	0	0	1	3	1	0	1	3	0	0	0	0	1	0
<i>Retinella indentata</i> (Say)	0	6	14	20	7	21	0	2	0	2	5	7	5	54	18	8	5	0	3	0
<i>Mesomphix cupreus</i> (Raf.)	4	7	4	2	1	5	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>Paravitrea significans</i> (Bland)	2	4	0	2	0	8	0	0	0	0	10	0	0	3	6	4	0	0	0	0
<i>P. sirsoni</i> (Pilsbry)	0	0	0	4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Paravitrea</i> sp.	19	34	78	52	2	24	0	0	0	0	0	4	0	3	6	5	0	0	0	0
<i>Hamula minuscula</i> (Binney)	0	0	0	1	0	15	0	0	0	0	0	8	3	25	11	2	0	0	0	1
<i>Lomitolites arboreus</i> (Say)	0	0	0	0	0	0	1	8	2	7	0	2	0	19	0	0	0	0	0	0
<i>Striatula militaris</i> (Morse)	0	0	1	0	0	0	0	0	0	9	11	27	0	39	43	8	12	6	1	0
<i>Dermoceras laeve</i> (Müller)	0	0	0	0	0	6	0	0	0	0	1	0	1	4	5	1	1	0	0	0
<i>Angulospira alternata</i> (Say)	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Helicodiscus parvulus</i> (Say)	0	1	0	3	3	10	2	0	0	0	0	0	1	26	2	0	0	0	0	0
<i>H. singularens</i> (Pilsbry)	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0
<i>Punctaria minutissima</i> (Lea)	66	110	488	204	40	109	0	0	9	4	26	52	228	55	53	9	31	1	9	0
<i>Eucnulus</i> sp.	2	2	4	1	0	18	0	0	0	1	1	8	0	4	25	5	0	0	1	7
<i>Strophospira latyphthalma</i> (Say)	11	41	62	46	0	16	0	1	15	3	3	0	10	3	8	4	4	0	0	0
<i>Strophospira</i> sp.	0	0	0	0	0	0	0	0	0	0	1	0	0	28	29	0	0	2	0	0
<i>Aspa armifera</i> (Say)	1	0	0	3	0	8	0	0	0	0	0	0	1	0	0	0	0	0	0	0
<i>A. ventricosa</i> (Say)	0	2	23	13	2	38	0	0	0	0	0	7	8	40	36	2	0	0	0	0
<i>A. ventricosa</i> (Say)	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>A. helixoides</i> (Sterki)	28	48	485	37	0	48	0	0	0	0	0	0	207	0	0	2	0	0	0	0
<i>A. perversa</i> (Say)	0	0	1	1	0	0	0	0	0	2	0	10	4	21	9	0	2	2	0	0
<i>Vertigo ovata</i> (Say)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
<i>Vertigo indentata</i> Wolf	2	0	0	0	0	0	0	0	0	0	0	4	0	1	5	1	0	0	1	1
<i>Vertigo</i> sp.	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Vertigo perspectiva</i> Clark	14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Vertigo</i> sp.	40	18	83	18	21	80	13	4	0	0	0	0	0	0	0	0	0	0	0	0
Juveniles	0	141	450	305	104	216	19	20	0	38	30	385	250	645	260	52	39	19	5	12

The modern samples may be grouped in a continuum of habitats reflecting increasingly drier conditions with Numbers 5, 6, 12, 13, 14 and 15 reflecting moist; Numbers 1, 2, 3, 4, 16, 17, 18, and 19 reflecting dry; Numbers 7, 8, 9, 10, 11 somewhat drier; and finally, Number 20 as the dry prairie habitat.

Prehistoric Gastropods

In excess of 25,000 terrestrial gastropods from horizons 1A through 8 were identified to provide information on environmental conditions. The bulk of these specimens are from Horizon 6 and above, very few being present in horizons 7 and 8 and none other than individuals which appear to have been intrusive have been recovered from older units. The gastropod assemblages, therefore, provide data on portions of approximately the past 7,000 years in this locality. Relative scarcity and total absence in the older stratigraphic units are doubtless a consequence of soil conditions unfavorable to gastropod abundance.

Some of the snails were recovered from a stratigraphic column in square 241NW75 which was removed in .25 ft. levels and processed by flotation and water screening utilizing a 0.4 mm mesh screen in the laboratory at the University of Wisconsin-Madison. Recording of volume of soil processed allows us to compute the abundance of gastropods per liter of soil volume. Table 8.2 pertains to successive horizons in this main excavation unit. Table 8.3 presents the identifications of gastropods from this column according to depth.

TABLE 8.2

Abundance of Gastropods by Horizons from
Stratigraphic Column in Square 241NW75

Horizon	Gastropods/liter	Age (B.P.)
1A	79.0	≤500
2B	133.0	2275
3B	108.0	3150
3C	59.0	3440
4A	20.0	3500-5100
4B	4.0	5100
5	142.0	6300-6700
6	210.0	6700-7500
7	9.0	7500-8100
8	0.2	8100-8600

It can be seen that one peak in gastropod abundance occurs in horizons 5 and 6. A second peak occurs in horizons 2B and 3B with a very marked tapering in abundance between horizon 3B and the deeper peak of 5 and 6. The low frequency of gastropods between the two peaks may either be a consequence of stress conditions (marked changes in temperature and/or increasing aridity) creating an unfavorable habitat for

TABLE 8.3

Gastropods from Laboratory-processed Stratigraphic Column in Square 241NW75, Rodgers Shelter

Species	Depth below datum (in feet)									
	3.30- 3.55	3.55- 3.80	3.80- 4.05	4.05- 4.30	4.30- 4.55	4.55- 4.80	4.80- 5.05	5.05- 5.30		
1. <i>Garychium exiguum</i> (Say)	0	0	0	7	13	7	1	0		
2. <i>Polygyra dorfeuilliana</i> Lea	1	0	0	1	0	3	0	1		
3. <i>Stenotrema</i> sp.	0	0	0	0	1	0	0	0		
4. <i>Mesodon elevatus</i> (Say)	0	0	0	0	0	1	0	0		
5. <i>M. inflectus</i> (Say)	1	0	0	1	0	0	0	0		
6. <i>Mesodon</i> sp.	1	0	0	0	0	0	0	0		
7. <i>Allogona profunda</i> (Say)	0	0	0	0	0	0	0	0		
8. <i>Retinella indentata</i> (Say)	5	2	2	4	9	6	2	0		
9. <i>Nesovitrenea electrina</i> (Gould)	0	1	0	0	0	0	0	0		
10. <i>Faravitrenea significans</i> (Bland)	1	0	0	0	0	0	0	0		
11. <i>Faravitrenea</i> sp.	1	0	2	1	2	0	0	0		
12. <i>Hawailia minuscula</i> (Binney)	35	36	0	63	0	0	1	0		
13. <i>Ventridens ligera</i> (Say)	0	0	0	0	1	0	0	0		
14. <i>Zonitoides arboreus</i> (Say)	0	0	1	2	5	3	0	0		
15. <i>Striatura milium</i> (Morse)	0	0	1	0	0	0	0	0		
16. <i>Striatura</i> sp.	0	0	1	0	12	9	0	2		
17. <i>Deroceras laeve</i> (Müller)	0	0	2	0	3	6	0	0		
18. <i>Anguispira alternata</i> (Say)	0	1	1	0	1	1	0	0		
19. <i>Helicodiscus parallelus</i> (Say)	3	2	5	11	9	11	9	6		
20. <i>H. singleyanus</i> (Pilsbry)	9	0	51	5	104	78	35	48		
21. <i>Functum minutissimum</i> (Lea)	5	2	0	1	4	1	1	1		
22. <i>Succinea</i> sp.	1	1	0	0	0	0	0	0		
23. <i>Strobilops labyrinthica</i> (Say)	1	0	0	8	1	1	0	0		
24. <i>Strobilops</i> sp.	2	1	0	0	5	0	1	0		
25. <i>Iastrocopta armifera</i> (Say)	3	0	2	4	16	10	1	0		
26. <i>G. contracta</i> (Say)	5	1	1	14	17	7	3	5		
27. <i>G. holzingeri</i> (Sterki)	2	0	1	1	6	0	1	2		

TABLE 8.3 (continued).

Species	Depth below datum (in feet)									
	3.30- 3.55	3.55- 3.80	3.80- 4.05	4.05- 4.30	4.30- 4.55	4.55- 4.80	4.80- 5.05	5.05- 5.30		
28. <i>G. pentodon</i> (Say)	2	0	0	0	9	5	1	1		
29. <i>G. procerus</i> (Gould)	2	1	0	0	2	1	1	1		
30. <i>Pupoides albilabris</i> (Adams)	0	0	0	0	0	0	0	0		
31. <i>Vertigo milium</i> (Gould)	0	0	0	0	0	0	0	0		
32. <i>V. tridentata</i> (Wolf)	0	0	0	0	1	0	0	0		
33. <i>Vallonia perspectiva</i> (Sterki)	6	3	0	1	0	0	0	0		
34. <i>Vallonia</i> sp.	15	9	6	3	7	5	0	0		
35. Juveniles	49	30	31	134	80	80	44	19		
No. liters soil processed	1.4	1.8	1.7	1.7	1.7	1.7	1.3	1.4		
No. snails per liter	107.1	50.0	62.9	153.5	181.2	138.2	77.7	59.3		
AQUATIC GASTROPODS	0	0	0	0	2	0	0	0		

TABLE 8.3 (continued)

Species	Depth below datum (in feet)															
	5.30- 5.55	5.55- 5.80	5.80- 6.05	6.05- 6.30	6.30- 6.55	6.55- 6.80	6.80- 7.05	7.05- 7.30	7.30- 7.55	7.55- 7.80	7.80- 8.05	8.05- 8.30				
1.	0	0	0	0	0	0	0	0	0	0	0	0				
2.	1	1	1	0	0	0	0	0	0	0	0	0				
3.	0	0	0	0	0	0	0	0	0	0	0	0				
4.	0	0	0	0	0	0	0	0	0	0	0	0				
5.	0	0	0	0	0	0	0	0	0	0	0	0				
6.	0	0	0	0	0	0	0	0	0	0	0	0				
7.	0	0	0	0	0	0	0	0	0	0	0	0				
8.	1	0	0	0	0	0	0	0	0	0	0	0				
9.	0	0	0	0	0	0	0	0	0	0	0	0				
10.	0	0	0	0	0	0	0	0	0	0	0	0				
11.	0	0	0	0	0	0	0	0	0	0	0	0				
12.	0	0	1	0	0	0	0	0	0	0	0	0				
13.	0	0	0	0	0	1	0	0	0	0	0	0				
14.	0	0	0	0	0	0	0	0	0	0	0	0				
15.	0	0	0	0	0	1	0	0	0	0	0	0				
16.	1	0	0	0	0	0	0	0	0	0	0	0				
17.	0	0	0	0	0	0	0	0	0	0	0	0				
18.	0	0	0	0	0	0	0	0	0	0	0	0				
19.	3	2	0	0	3	1	1	0	0	0	0	0				
20.	32	12	9	6	10	9	2	0	0	0	0	0				
21.	0	0	0	0	0	0	0	0	0	0	0	0				
22.	0	0	0	0	0	0	0	0	0	0	0	0				
23.	0	0	0	0	0	0	0	0	0	0	0	0				
24.	0	0	0	0	0	0	0	0	0	0	0	0				
25.	1	0	0	0	0	0	0	0	0	0	0	0				
26.	3	2	4	0	0	0	0	0	0	0	0	0				
27.	0	3	0	1	0	1	0	0	0	0	0	0				

TABLE 8.3 (continued)

Species	Depth below datum (in feet)													
	5.30- 5.55	5.55- 5.80	5.80- 6.05	6.05- 6.30	6.30- 6.55	6.55- 6.80	6.80- 7.05	7.05- 7.30	7.30- 7.55	7.55- 7.80	7.80- 8.05	8.05- 8.30		
28.	1	0	1	0	0	0	0	0	0	0	0	0		
29.	7	1	1	1	0	1	0	0	0	0	0	1		
30.	3	3	0	0	0	0	0	0	0	0	0	0		
31.	0	0	0	0	0	0	0	0	0	0	0	0		
32.	0	0	0	0	0	0	0	0	0	0	0	0		
33.	0	0	0	0	0	0	0	0	0	0	0	0		
34.	0	0	0	0	1	0	0	0	0	0	0	0		
35.	11	6	9	4	0	4	1	3	2	0	0	0		
No. liters	1.4	1.4	1.5	1.4	1.7	1.4	1.4	1.8	2.1	2.2	2.2	2.1		
Sn/lt.	45.7	21.4	17.5	8.6	8.2	11.4	3.6	1.7	1.0	0	0	0		
AQUATIC	0	0	0	0	0	0	0	0	0	0	0	0		

TABLE 8.3 (continued)

Species	Depth below datum (in feet)													
	8.30- 8.55	8.55- 8.80	8.80- 9.05	9.05- 9.30	9.30- 9.55	9.55- 9.80	9.80- 9.55	9.55- 9.80	9.80- 10.05	10.05- 10.30	10.30- 10.55	10.55- 10.80	10.80- 11.05	
1.	1	1	7	29	26	57	132	156	120	48	46			
2.	0	0	0	0	0	0	0	0	2	2	0			
3.	0	0	0	0	0	0	0	0	0	0	0			
4.	0	0	0	0	0	0	0	0	0	0	0			
5.	0	0	0	0	0	0	0	0	0	0	0			
6.	0	0	0	0	0	0	0	0	0	0	0			
7.	0	0	2	0	0	1	0	7	5	1	1			
8.	0	2	1	3	6	5	9	13	10	0	2			
9.	0	0	0	0	0	0	0	0	0	0	0			
10.	0	0	0	0	0	0	0	0	0	0	0			
11.	0	0	0	0	0	0	0	0	1	0	0			
12.	2	13	18	31	35	11	12	78	66	20	38			
13.	0	0	0	0	0	0	0	0	0	0	0			
14.	0	1	2	4	0	0	0	5	13	0	1			
15.	0	0	0	0	0	0	12	2	2	0	0			
16.	0	0	0	0	0	4	0	28	8	0	0			
17.	0	1	0	3	0	6	8	12	5	1	4			
18.	1	1	3	10	10	10	8	18	14	16	5			
19.	0	0	4	5	3	5	2	5	1	3	1			
20.	4	19	54	59	57	39	5	24	4	1	0			
21.	1	8	11	17	16	11	6	30	13	8	9			
22.	0	0	0	3	0	0	0	0	0	0	0			
23.	0	0	0	0	1	4	13	1	4	8	10			
24.	0	0	4	1	6	0	0	14	16	0	0			
25.	0	0	4	3	2	1	0	0	1	2	1			
26.	1	15	29	42	44	58	80	100	72	38	26			
27.	0	6	11	14	24	10	6	6	5	4	4			

TABLE 8.3 (continued)

Species	Depth below datum (in feet)											
	8.30- 8.55	8.55- 8.80	8.80- 9.05	9.05- 9.30	9.30- 9.55	9.55- 9.80	9.80- 10.05	10.05- 10.30	10.30- 10.55	10.55- 10.80	10.80- 11.05	
28.	0	0	5	11	2	2	4	0	1	3	0	
29.	1	3	4	4	3	2	0	1	1	0	1	
30.	0	1	0	1	0	1	0	2	0	0	1	
31.	0	0	0	0	0	0	0	1	0	0	0	
32.	0	0	0	0	0	0	0	0	0	0	0	
33.	0	1	4	10	12	5	0	3	1	1	0	
34.	2	56	118	194	141	53	3	33	27	6	10	
35.	9	70	172	177	331	324	269	144	114	186	195	
No liters	2.1	2.1	2.0	2.1	2.2	2.0	2.1	2.3	2.0	2.0	2.3	
Sn/lt	10.0	94.3	226.5	295.7	342.4	304.5	271.0	297.0	253.0	174.0	154.3	
AQUATIC	0	0	0	1	4	2	0	3	1	0	0	

TABLE 8.3 (continued)

Species	Depth below datum (in feet)											
	11.05- 11.30	11.30- 11.55	11.55- 11.80	11.80- 12.05	12.05- 12.30	12.30- 12.55	12.55- 12.80	12.80- 13.05	13.05- 13.30	13.30- 13.55		
1.	50	6	2	1	0	0	0	0	0	0		
2.	0	0	0	0	0	0	0	0	0	0		
3.	0	0	0	0	0	0	0	0	0	0		
4.	0	0	0	0	0	0	0	0	0	0		
5.	0	0	0	0	0	0	0	0	0	0		
6.	0	0	0	0	0	0	0	0	0	0		
7.	0	1	0	0	0	0	0	0	0	0		
8.	0	1	0	0	0	0	0	0	0	0		
9.	0	0	0	0	0	0	0	0	0	0		
10.	0	0	0	0	0	0	0	0	0	0		
11.	0	0	0	0	0	0	0	0	0	0		
12.	17	11	0	1	0	0	0	0	0	0		
13.	0	0	0	0	0	0	0	0	0	0		
14.	0	0	0	0	0	0	0	0	0	0		
15.	0	0	0	0	0	0	0	0	0	0		
16.	0	0	0	0	0	0	0	0	0	0		
17.	1	0	0	0	0	0	0	0	0	0		
18.	2	2	0	0	0	0	0	0	0	0		
19.	0	0	0	0	0	0	0	0	1	0		
20.	5	0	0	0	0	0	0	0	0	0		
21.	3	0	0	0	0	0	0	0	0	0		
22.	0	0	0	0	0	0	0	0	0	0		
23.	5	0	0	0	0	0	0	0	0	0		
24.	0	0	0	0	0	0	0	0	0	0		
25.	0	0	0	0	0	0	0	0	0	0		
26.	26	3	3	0	0	0	0	0	0	0		
27.	3	0	0	0	0	0	0	0	0	0		

TABLE 8.3 (continued)

Species	Depth below datum (in feet)											
	11.05- 11.30	11.30- 11.55	11.55- 11.80	11.80- 12.05	12.05- 12.30	12.30- 12.55	12.55- 12.80	12.80- 13.05	13.05- 13.30	13.30- 13.55		
28.	3	0	0	0	0	0	0	0	0	0		
29.	1	1	0	0	0	0	0	0	0	0		
30.	1	0	0	0	0	0	0	0	0	0		
31.	0	0	0	0	0	0	0	0	0	0		
32.	0	0	0	0	0	0	0	0	0	0		
33.	1	0	0	0	0	0	0	0	0	0		
34.	5	0	0	0	0	0	0	0	0	0		
35.	123	39	4	0	0	0	0	0	0	0		
No liters	2.2	2.0	2.1	2.3	2.1	2.1	2.0	2.0	1.7	1.8		
Sn/lt	110.5	32.0	4.3	.9	0	0	0	0	.59	0		
AQUATIC	0	0	0	0	0	0	0	0	0	0		

TABLE 8.3 (concluded)

Species	Depth below datum (in feet)		
	13.55- 13.80	13.80- 14.05	14.05- 14.30
1.	0	0	0
2.	0	0	0
3.	0	0	0
4.	0	0	0
5.	0	0	0
6.	0	0	0
7.	0	0	0
8.	0	0	0
9.	0	0	0
10.	0	0	0
11.	0	0	0
12.	0	0	0
13.	0	0	0
14.	0	0	0
15.	0	0	0
16.	0	0	0
17.	0	0	0
18.	0	0	0
19.	0	0	0
20.	0	0	0
21.	0	0	0
22.	0	0	0
23.	0	0	0
24.	0	0	0
25.	0	0	0
26.	0	0	0
27.	0	0	0
28.	0	0	0
29.	0	0	0
30.	0	0	0
31.	0	0	0
32.	0	0	0
33.	0	0	0
34.	0	0	0
35.	0	1	1
No. liters	1.8	1.7	2.0
Sn/liter	0	.59	.5
AQUATIC	0	0	0

gastropods or a consequence of calcium depletion in the deposit which might, in turn, lead to the loss of shells. Differential preservation can result if there are periods of surface stability when rapid deposition ceases which would then be accompanied by the removal of calcium from the soils down to the lower limits to which surface waters penetrate.

To be more precise about the nature of the climatically induced changes taking place, we may turn to the character of the gastropod assemblages associated with the horizons. The distribution of the various species reveals a pattern which contrasts selected strata (Table 8.4).

TABLE 8.4

Percent of Nine Selected Species in Three Strata

Species	Surface	Hor. 5	Hor. 6
<i>Carychium exiguum</i>	.16	.13	.23
<i>Retinella indentata</i>	.04	.03	.03
<i>Paravitrea</i> sp.	.05	.11	.15
<i>Striatura milium</i>	.03	.01	.02
<i>Punctum minutissimum</i>	.29	.04	.04
<i>Strobilops labyrinthica</i>	.06	.06	.06
<i>Gastropoda contracta</i>	.04	.14	.17
<i>G. holzingeri</i>	.18	.02	.01
<i>Vallonia perspectiva</i>	.06	.18	.06
Totals	.91	.72	.80

While the prehistoric horizons in Table 8.4 are not identical to the modern litter collections, it is obvious that they reflect very similar conditions.

By contrast, the upper archaeological levels from horizons 1A through 4B reflect the prominence of a different group of species (Table 8.5).

TABLE 8.5

Percent of Five Stress-Tolerant Species in Horizons 1A through 4B

Species	1A	2B	3A	3B	3C	4A	4B
<i>Hamata minuscula</i>	.07	.05	.00	.00	.00	.01	.00
<i>Louilella arborus</i>	.11	.05	.11	.13	.00	.00	.01
<i>Helicodiscus parallelus</i>	.27	.19	.23	.19	.00	.20	.43
<i>H. singleyanus</i>	.09	.20	.16	.23	.15	.32	.28
<i>Gastropoda armifera</i>	.05	.08	.08	.11	.00	.04	.05
Totals	.59	.57	.59	.67	.85	.57	.77

The cluster of species that comprise the majority of specimens from the upper levels (Table 8.5:Horizons 1A through 4B) are among the most widely distributed of North American gastropods. As such, they provide little specific information as to habitat characteristics for as a group they tolerate diverse stress conditions. If we take the two assemblages and tabulate their abundance in relation to the wet-dry continuum suggested in conjunction with the discussion of the modern snails, some changes do emerge:

	Moist	Dry	Drier	Prairie
% First Group (Table 8.4)	.94	.997	.84	.00
% Second Group (Table 8.5)	.06	.003	.16	100.00

The second group (Table 8.5), characterizing horizons A1 through 4B, does seem to reflect drier conditions than prevailed on horizons 5 and 6. A word of caution is appropriate to indicate that the strong prairie component is based upon a single gastropod.

As indicators of the specific character of conditions, we need to look for other gastropods that are present, not necessarily in large numbers, but having a pattern of distribution such that they are absent in modern litter collections and absent in Horizons 5 and 6 but present in the intervening zones. Specimens falling into this category include *Triodopsis albolabris*, *Haplotrema concavum*, *Nesovitrea electrina*, *Ventridens demissus*, and *Ventridens ligera*.

This particular complex is also not especially informative. *Haplotrema concavum* is a carnivore and its presence would thus only imply the presence of other snails. *Nesovitrea electrina* has the extremely broad distribution characteristic of the cluster of five that defined the top zone (Table 8.5). The remaining three species suggest a complex better suited to an eastern and particularly southeastern habitat which might imply warm, moist conditions. However, there are also indications in their specific habitat that they can tolerate more open conditions than simply a dense wooded habitat thus making warm and dry equally appropriate. Using the same procedure with the first assemblage isolated permits us only to add *Vertigo milium*, a snail with an extremely wide distribution. None of the other gastropods are limited to the surface and horizons 5 and 6 but occur in association with the other assemblages as well, though in a reduced abundance. It is evident that we need to turn to a more precise measure of changing environmental conditions. Prior to this, however, we need to indicate that the changing proportions of the species were based not only on the gastropods recovered from the column in square 241NW75 but also from additional specimens recovered in field flotation. Table 8.6 present the gastropods from the correlated horizons at Rodgers Shelter, recovered through field flotation. We shall draw upon these specimens, as well as other specimen lots where the total sample has not been identified, in a metrical analysis of the gastropods.

In our classification of the Pupillidae, we followed the interpretation of Bequaert and Miller (1973:88-89) in regarding *Gastrocypa pentodon* and *G. tappaniana* as extremes of a single continuum and placed all specimens under the designation *pentodon*. These two taxa are mainly differentiated on the basis of size, and of these attributes the length measurement for *pentodon* is 1.5 to 1.8 mm and that for *tappaniana* 1.7 to 2.0 mm. If we make 1.8 mm a dividing line and contrast

TABLE 8.6

Gastropods from Correlated Horizons at Rodgers Shelter

Species	Horizon						
	1A	2B	3A	3B	4A	4B	5
1. <i>Carychium exiguum</i> (Say)	0	0	0	0	0	0	479
2. <i>Polygyra donfeuillicana</i> (Lea)	38	34	5	17	34	0	2
3. <i>Stenotrema</i> sp.	0	0	0	0	34	0	0
4. <i>Mesodon elevatus</i> (Say)	0	0	0	0	1	0	0
5. <i>M. inflectus</i> (Say)	20	38	0	15	9	0	0
6. <i>Mesodon</i> sp.	61	60	6	29	0	0	31
7. <i>Triodopsis albolabris</i> (Say)	1	1	0	0	0	0	0
8. <i>Allongona profunda</i> (Say)	0	0	0	1	1	0	93
9. <i>Haplotrema concavum</i> (Say)	7	0	0	5	0	1	0
10. <i>Euconulus</i> sp.	2	0	0	0	0	0	0
11. <i>Retinella indentata</i> (Say)	71	41	18	64	9	1	111
12. <i>Mesovitrea electrina</i> (Gould)	0	0	0	0	0	0	0
13. <i>Mesomphyr cupreus</i> (Say)	1	0	0	0	1	0	0
14. <i>Paravitrea capsella</i> (Gould)	0	7	2	6	0	1	91
15. <i>P. simpsoni</i> (Pilsbry)	0	1	0	0	0	0	0
16. <i>P. stigmificans</i> (Bland)	17	46	7	9	1	0	0
17. <i>Paravitrea</i> sp.	4	0	2	4	1	0	1
18. <i>Hemastoma minuscula</i> (Binney)	5	6	0	4	2	0	392
19. <i>Ventridens demissus</i> (Binney)	0	2	2	6	2	0	0
20. <i>V. tigers</i> (Say)	0	0	0	1	0	0	0
21. <i>Ventridens arboreus</i> (Say)	119	63	46	154	2	1	129
22. <i>Striatum milium</i> (Morse)	0	0	0	0	0	2	64
23. <i>Denticulus laevis</i> (Müller)	1	0	0	0	0	0	1
24. <i>Angustolina albertina</i> (Say)	7	5	14	3	0	0	241
25. <i>Helicospira parviretus</i> (Say)	283	260	98	213	78	49	23
26. <i>H. pingueyanus</i> (Pilsbry)	84	132	66	180	72	22	257
27. <i>Functum minutissimum</i> (Lea)	0	0	0	0	0	0	133
28. <i>Succinea</i> sp.	0	1	1	7	0	0	0
29. <i>Strophilops labyrinthica</i> (Say)	54	54	21	41	3	3	234
							129

TABLE 8.6 (concluded).

Species	Horizon								
	1A	2B	3A	3B	4A	4B	5	6	7
30. <i>Strobilops</i> sp.	0	0	0	0	0	0	0	0	0
31. <i>Gastrocopta armifera</i> (Say)	56	98	24	137	16	6	3	0	0
32. <i>G. contracta</i> (Say)	84	167	77	115	26	11	454	156	20
33. <i>G. corticaria</i> (Say)	2	1	1	1	0	0	0	0	0
34. <i>G. holzingeri</i> (Sterki)	0	0	1	0	0	0	18	1	1
35. <i>G. pentodon</i> (Say)	0	0	0	0	0	0	6	4	2
36. <i>G. procera</i> (Gould)	0	2	2	1	2	1	5	0	0
37. <i>Pupoides albilabris</i> (Adams)	4	33	7	19	19	0	3	0	0
38. <i>Vertigo milium</i> (Gould)	0	0	0	0	0	0	0	0	0
39. <i>V. tridentata</i> (Wolf)	0	1	1	0	0	0	1	0	0
40. <i>Columella</i> sp.	0	0	1	0	0	0	0	0	0
41. <i>Vallonia perspectiva</i> (Sterki)	2	3	6	9	8	2	7	6	0
42. <i>Vallonia</i> sp.	0	0	0	1	2	3	220	90	27
43. <i>Bulimulus dealbatus</i> (Say)	0	2	0	0	0	0	0	0	0
44. Juveniles	31	37	49	73	8	3	847	1198	33
45. AQUATIC GASTROPODS	0	4	0	0	1	0	0	0	0

the specimens which fall above and below this point, the following distribution results (Table 8.7).

TABLE 8.7

Distribution of *Gastrocopta pentodon* by Length

Length	Modern	3B	Horizon			
			4A	5	6	7
Below 1.8 mm (dry)	26	2	2	64	56	1
Above 1.8 mm (wet)	16	0	0	1	1	0

Modern litter collections contain the highest proportion of large specimens reflecting moist conditions (Table 8.7). As one would expect, horizons 5 and 6 are most similar but have only a small proportion of moist indicators though these are entirely lacking on the other horizons having measurable *pentodon*. This interpretation would also seem to be confirmed if we contrast the length of *G. pentodon* from the modern litter samples. The specimens from the moist habitat (N = 35) have a mean length of 1.82 mm. Those from all of the drier habitats (N = 6) have a mean length of 1.63 mm. Thus this line of evidence would seem to be congruent with the species assemblages and further indicate that the upper horizons reflect drier conditions rather than moister conditions.

Metrical Analysis

The utilization of the size differences between the large *Gastrocopta luttaniana* ? and small forms of *Gastrocopta pentodon* as an indicator of environmental change, will serve as an introduction to what may well prove to be the most precise use of gastropods for environmental interpretation. It has been obvious for some time--indeed the earlier literature on gastropods abounds in illustrations and the topic was dealt with at length by Rensch in 1932--that there are size changes associated with environmental differences. When an adequate series of measured specimens is analyzed and particularly when size differences are plotted on a map, it is seen that the size changes form a pattern of clines. The association of such clines with climatic variables makes it possible to develop a series of regression equations that allow one to take the mean dimensions of measured specimens of an appropriate species found in an archaeological horizon, substitute this value in the regression equation and thereby secure the appropriate climatic parameter for that horizon. This procedure was used in conjunction with the analysis of the gastropods from the Cherokee Sewer Site in northwestern Iowa to reconstruct climatic conditions in that region for a time span roughly the equivalent of Rodgers Shelter (Baerreis ms.). For example, making use of the distribution of modern specimens of *Carychium eximium*, it was found that there was a significant negative correlation between mean length and at least four climatic values (Table 8.8).

Since to be significantly different from zero, the correlation coeffi-

TABLE 8.8

Distribution of modern *Carychium exiguum*

	Mean Length	Growing Season	July Temperature	January Temperature
Growing Season	-.810			
July Temperature	-.714	.855		
January Temperature	-.819	.832	.902	
Annual Precipitation	-.822	.756	.489	.966

cient should be 0.553 or higher for $p = 0.05$, one can make use of the regression coefficient for all four of these measures. The regression equations for the estimation of x from y for *Carychium exiguum* are as follows:

$$\begin{aligned} \text{Growing Season} \quad y &= 2.685 - 0.00545x \quad (x = \frac{y - 2.685}{.00545}) \\ \text{July Temperature} \quad y &= 3.920 - 0.02876x \quad (x = \frac{y - 3.92}{.02876}) \\ \text{January Temperature} \quad y &= 2.077 - 0.01327x \quad (x = \frac{y - 2.077}{.01327}) \\ \text{Annual Precipitation} \quad y &= 2.550 - 0.02212x \quad (x = \frac{y - 2.55}{.02212}) \end{aligned}$$

Measurements of adult specimens of *C. exiguum* from Rodgers Shelter are given in Table 8.9. Horizons 5 and 6 both have sufficient numbers present to permit a reliable reconstruction of the climatic variables. When we substitute the means of 1.68 and 1.69 for y in the regression equations, we arrive at the data presented in Table 8.10.

TABLE 8.9

Measurements of Adult Specimens of *Carychium exiguum*, Rodgers Shelter

Location	No. Specimens	Range (mm)	Mean	S.D.
Modern Litter	383	1.50 - 2.18	1.78	.0999
Horizon 1A	1	1.66		
Horizon 2B	5	1.58 - 1.81	1.68	.0850
Horizon 3B	1	1.60		
Horizon 5	219	1.49 - 1.88	1.68	.0741
Horizon 6	237	1.52 - 1.89	1.69	.0729
Horizon 7	11	1.63 - 1.77	1.66	.0324

The values of the above reconstructions are not markedly different from those of today shown in the last line of Table 8.10; a slightly longer growing season (the period between the last killing frost of spring and the first killing frost of fall), virtually identical July

TABLE 8.10

Reconstruction of Climatic Variables for Three Strata

Horizon	Mean	Growing Season (days)	July Tempera- ture	January Tempera- ture	Annual Precipitation	Date
5	1.68	184.4	77.9°F	29.9°F	39.3"	6300-6700 B.P.
6	1.69	182.6	77.5°F	29.2°F	38.9"	6700-7500 B.P.
Modern		175.0	78.0°F	32.0°F	42.0"	(modern)

temperatures, and slightly less annual precipitation. These values, of course, are in harmony with the interpretation previously suggested that Horizons 5 and 6 are quite similar to the present.

To secure comparable information on the horizons associated with the second snail assemblage (Table 8.5) requires a measurable specimen, sensitive to environmental changes, present in the appropriate horizons or ideally in all horizons. One such is *Polygyra dorfeuilliana* (Lea) (Table 8.11) for which a series of shell measurements was made by Branson (1970:30) who indicated "...the presence of a weakly developed cline extending from the more arid regions toward the east." Since Branson's measurements are presented in terms of four extremely large areas rather than individual stations, they cannot be used as the basis for construction of a series of regression equations or indeed establish whether temperature or precipitation is the controlling environmental variable. Differences in size association with the sequent horizons confirm the fact that Horizons 5 and 6 (and additionally Horizon 7) are distinct from horizons 1A through 4A but in some environmental variable that is shared with the upper levels and modern conditions. As measurements of the collection continue and the modern clines are established, these climatic or environmental variables should be reconstructed with some precision.

TABLE 8.11

Maximum Diameter (mm) of *Polygyra dorfeuilliana*
from Rodgers Shelter

mm	Litter	1A	2B	3A	3B	4A	5	6	7
7.1							1	2	
7.2							1		
7.3								1	
7.4								1	
7.5						1		2	
7.6	1						1	1	1
7.7			1		1		1	1	1
7.8		1	1		4	2	1		1
7.9	2	1			1		1	1	
8.0		2			5	3			
8.1		3	4	1	3	1	1		
8.2	1	5	2	3	6	4			
8.3		3	2	2	4	6			
8.4	1	5	2	3	3	5			
8.5	4	2	1	4	3				
8.6	2	3	2	2		5			
8.7		5		2	2	3			
8.8	1	4	3	1	2				
8.9		3	1			2			
9.0	1		3			2			
9.1		1	1						
9.2	1	2	1						
...									
9.7		1							
Mean	8.44	8.52	8.49	8.45	8.20	8.37	7.60	7.46	7.69

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CHAPTER 9

THE ENVIRONMENTAL IMPLICATIONS OF THE FAUNA RECOVERED FROM RODGERS SHELTER

James R. Purdue

McMillan (1976) proposed a model of cultural change at Rodgers Shelter based, in part, on analysis of faunal remains. The ecological aspect of his hypothesis is that during the Hypsithermal (3000 to 8500 B.P.) significant habitat changes occurred in response to a drier climate such that upland woody vegetation was replaced by prairie while riparian areas assumed a drier nature. McMillan cited as faunal evidence the occurrence of bison, pronghorn, prairie chicken, jackrabbit, spotted skunk, badger, and pocket mouse and the concurrent decrease in relative numbers of deer and raccoon remains between 6000 and 8000 B.P. In this reanalysis of Rodgers Shelter, the central objective is to search out data that will support, revise, or refute McMillan's hypothesis. The data base consists of the materials recovered by McMillan during the 1960's, by McGrath in 1974, and by Kay in 1976.

Paleoecological reconstructions of faunal resources are fraught with difficulties, especially when the span of time is great, as it is at Rodgers Shelter. There is no data base for pre-settlement animal populations comparable with the one available for major vegetation. And, as F. King has shown (Chapter 2) studies of pre-settlement vegetation are of limited use in projecting past changes through a major climatic event, i.e., the Hypsithermal that occurred several millennia before the 1830's. Smith (1975) used a number of wildlife studies as a basis for projecting exploitation of animal populations by Middle Mississippian peoples in the central Mississippi Valley. His job was considerably easier than ours because he did not have to deal with cultural change through a major climatic shift. Even so, one must apply findings of modern studies to the prehistoric context with great care.

The effects of wholesale environmental change caused by Europeans are not often realized. Agricultural practices have altered habitat and food sources for wildlife. Predation regimes have changed with the removal of predators and substitution of modern hunting practices. The introduction of exotic plant and animal species has had effects in terms of food sources and competitors. For example, wild turkey and white-tailed deer were numerous in pre-settlement Missouri; by 1925, their state-wide numbers were extremely low, i.e., 4000 turkeys, 400 deer (Bennitt and Nagel 1937). Through game management in the last fifty years, both species have once again built up sizable population levels. Great density flux and concomitant adjustments obviously have occurred during the last 200 years. However, some biological parameters would not be greatly altered by these perturbations (qualitative sex and age characters, generalized food and habitat preferences), but others would be (density, specific food sources, and several quantitative characteristics).

The animal species that occur at a particular place and time are the result of dynamic abiotic and biotic factors. Species ranges have

shifted through time, which is obvious from just a cursory look at the Pleistocene record. Forms that exist today in the far north are commonly found in Pleistocene deposits in the midwestern United States. Lundelius (1964) notes that a study of range changes can be valuable, particularly for extant species with known ecological preferences. However, he notes some problem areas, particularly along large river systems that provide an avenue for the temporary occurrence of inappropriate forms. Findley (1964) lists several other reservations, one of which concerns broad tolerances of common species. Little paleoecological information is imparted by the mere presence of these forms. Additionally, ecological preferences of species can be altered through time by evolutionary changes of physiological tolerance or by arrival of a competitor. Findley (1964) gives an example of *Peromyscus truei* which is usually associated with Pinyon-Juniper forests in the southwest. Some populations, however, with different competitors are found in pine forests, chaparral, fir forest, and sand dunes. Recent work by Van Devender (1977 and pers. comm.) has indicated drastic habitat shifts by some desert animals in the late Pleistocene-early Holocene.

The Rodgers Shelter fauna consists of extant species, although the status of some has been drastically altered by Europeans. The time involved is short, in the geological sense, so that evolutionary changes are probably small. McMillan (1976) examined evidence for shifts in geographic ranges in his analysis of the Rodgers skeletal material. Initially, he compiled a list of species that probably resided in the area 150 years ago. He then noted the arrival and departure of additional species through the ten millennia of the Rodgers record. Faunal material recovered from 1974 and 1976 will be examined and compared to McMillan's findings.

One of the shortcomings of the excavations carried out in the 1960's at Rodgers Shelter was the lack of a consistent recovery system from top to bottom (Chapter 3). This methodological problem was corrected for in 1974 and 1976, when fine-scale recovery was conducted systematically at all levels. These excavations produced material suitable for detailed analysis of deposition patterns.

Many taxa are represented in the Rodgers fauna. Some are common, others are rare. Many are present as the result of human behaviors, while others are deposited in consequence to other agents. Multivariate analysis, particularly factor analysis, will be used to summarize and elucidate deposition patterns. An attempt will be made to interpret the results in terms of cultural and environmental meaning.

In modern homeothermic animals, many species vary in body size throughout their geographic range. The usual case is for large individuals to be found in northern latitudes and small ones in the south. Traditionally, this is known as the Bergmann response, so named after the 19th century originator of the idea (See James 1970 for excerpted quotations of Bergmann and subsequent redefinition of his "Rule"). Initially, it was thought that a large body size in colder climates was strictly related to heat conservation, i.e., proportionally less surface area through which to lose body heat. Recently, this explanation for Bergmann's Rule has been found to be too simplistic. Other factors that must be considered are the presence or absence of potential competitors, food size, habitat productivity, and other ecological parameters, e.g.,

species diversity, equilibrium niche size (see Rosenzweig 1968 and McNab 1971 for critiques).

In spite of confusion about causal factors, many species do show geographic variation in body size (Table 9.1). Most species that vary in body size are larger in the north, but some have opposite clines (Table 9.1). Clines through time, e.g., through Pleistocene climatic change, that parallel today's latitudinal clines have been reported for a number of species (Hibbard 1963; Guilday *et al.* 1964; Guilday *et al.* 1977). All of these studies emphasize north-south size change, but when more complete modern data are available, more complex patterns emerge (James 1970; Mengel and Jackson 1977). These last two studies indicate that body size clines may be quite sensitive to environmental factors. Clines were not only modified by mountain ranges and major river valleys, but also shift to the west along the western border of the deciduous forest (Figure 9.1).

TABLE 9.1

Eastern North American Mammals having Geographic Clines
in Body Size between 30° - 40° Latitude*

Species	Correlation with Latitude**	Species	Correlation with Latitude**
<i>Didelphis virginiana</i>	-	<i>Lynx rufus</i>	+
<i>Scalopus aquaticus</i>	+	<i>Marmota monax</i>	+
<i>Blarina brevicauda</i>	+	<i>Sciurus carolinensis</i>	+
<i>Ursus americanus</i>	-	<i>Sciurus niger</i>	-
<i>Procyon lotor</i>	+	<i>Geomys bursarius</i>	+
<i>Mustela erminea</i>	+	<i>Pitymys pinetorum</i>	+
<i>Mephitis mephitis</i>	+	<i>Ondatra zibethicus</i>	+
<i>Canis lupus</i>	+	<i>Erethizon dorsatum</i>	+

** + Indicates body size increases towards the north.

- Indicates body size decreases towards the north.

* Modified from McNab (1971)

It has been postulated by McMillan (1976) that Hypsithermal-related events resulted in significant ecological changes in the biota around Rodgers Shelter. We will, therefore, try to detect changes in body size of selected species that occur at Rodgers Shelter.

The program outlined in this chapter is perhaps overly ambitious. One of the limiting factors in making inferences about past animal populations is the lack of comparative ecological data. Ecological and morphological relationships between organisms and their total environment are usually complex. Past ecologies would have been equally complex. Attempts to model prehistoric habitat and species compositions often have not taken this innate complexity into account and must be viewed with reservation. Many studies on modern animals need to be done

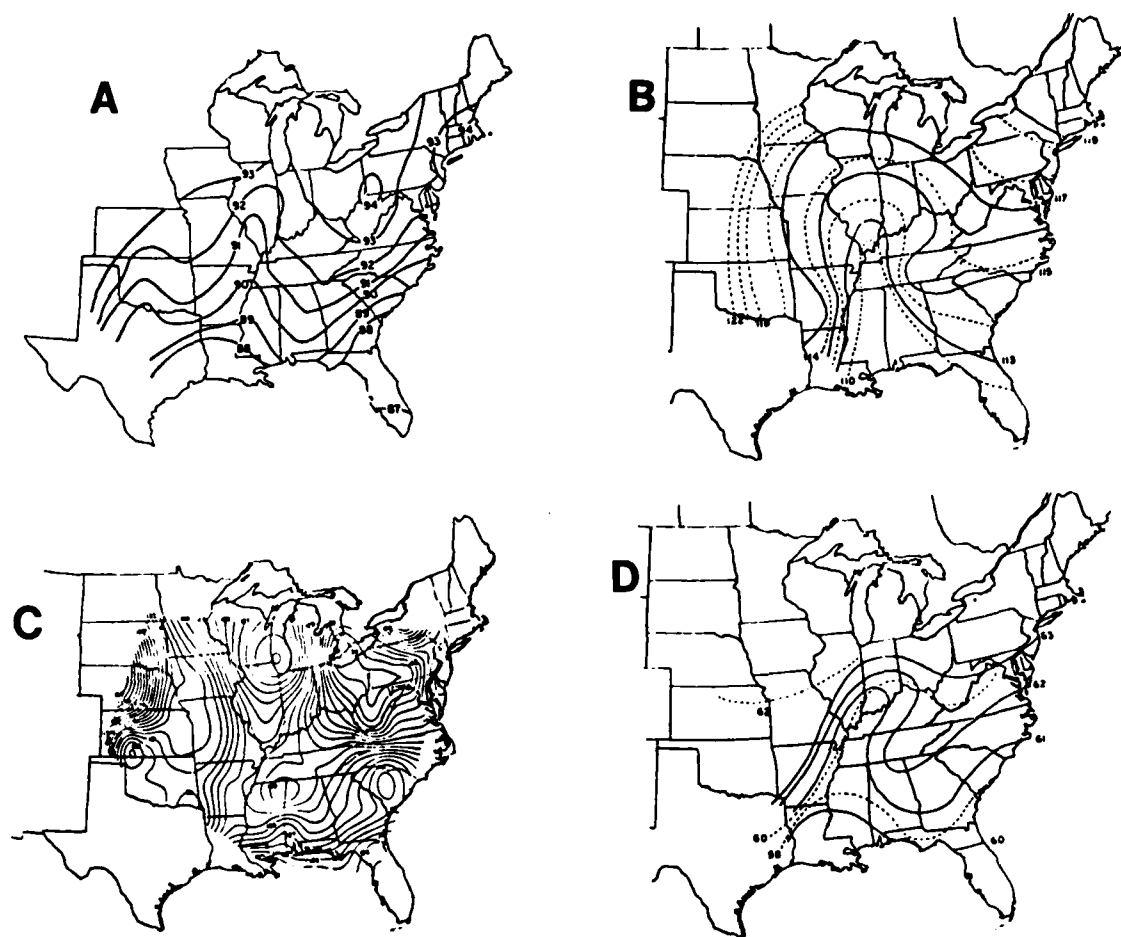


Figure 9.1. Change in body size as indicated by wing length, in four bird species. Contour lines are isophenes for wing length. A. Downy Woodpecker (*Dendrocopos pubescens*) (Contour interval 1 mm). B. Hairy Woodpecker (*Dendrocopos villosus*) (Contour interval 2 mm). C. Male Blue Jay (*Cyanocitta cristata*) (Contour interval 0.5 mm). D. Carolina Chickadee (*Parus carolinensis*); unbroken lines are for males, broken lines are for females (Contour interval 2 mm). Figure modified from James (1970).

before all potential information contained in the Rodgers Shelter fauna can be interpreted. We have, therefore, restricted our analysis to a point where reasonable conclusions can be drawn from both prehistoric and available modern data. These data are most suited to looking at qualitative responses to major climate shifts as well as providing a gross overview of Holocene animal exploitation along the western flank of the Ozark Highland.

METHODS

The studies are mainly based on bone collected from excavations conducted in 1974 and 1976. Although some bone from the pre-1970 work was used to augment the morphological studies. Material was available from three points on the site: under the overhang (1974); in front of the overhang (1976); and on the west terrace (1976). See Chapter 3 for excavation details.

Identifications of bone were made only after direct comparison to modern skeletal specimens. Nevertheless, some taxa presented special problems and are listed below:

Fish. Time constraints resulted in fish being identified to family level (with some exceptions), although many elements could have been taken to finer taxonomic levels. Identifications were done by Dr. Bonnie W. Styles and Kira Silverbird.

Herptiles and Birds. Time problems also restricted the level of amphibian, reptile, and bird identifications to higher taxa. Obvious finer subdivisions, e.g., *Terrapene* sp., *Meleagris gallopavo*, were made for some forms. The remaining taxa were lumped in two heterogeneous groups listed as miscellaneous herptiles and miscellaneous birds.

This treatment of fish, herptiles, and birds is obviously not ideal. There is necessarily a loss of information, particularly involving environmental considerations. Studies of broad patterns of deposition, however, are not greatly affected. It is our intention to reexamine the material in greater detail at a later time.

Canis. No attempt was made to separate coyote (*C. latrans*) from domestic dog (*C. familiaris*). Both forms are probably present in the site (Parmalee *et al.* 1976; McMillan 1970), but, since both forms are highly variable, it was not felt that reliable specific identification could be made.

Sciurus. Two species, gray squirrel (*S. carolinensis*) and fox squirrel (*S. niger*), are present in the faunal material. Discriminant function analysis, based on large modern samples, was used on selected elements to separate the species. Results of the analysis will be presented later in connection with the morphological studies. For depositional analysis all elements were referred to *Sciurus* sp.

Geomys bursarius. All gopher material was referred to the plains pocket gopher (*Geomys bursarius*). The possibility of *Thomomys* or *Cratogeomys* being present during the Hypsithermal was discounted because of two distinct grooves on the I¹ and *Geomys*-like enamel pattern on the molars (Saunders 1977).

Peromyscus. Two species of deer mouse (*P. leucopus* and *P. maniculatus*) are probably represented. No attempt was made to separate the two, even though Semken (1977) has done so through use of measurements

on the mandibles, in northern Iowa. Insufficient modern material and understanding of prehistoric variation make such determinations from western Missouri inadvisable.

Small microtines. The species that are considered potentially present were southern bog lemming (*Synaptomys cooperi*), pine vole (*Pitymys pinetorum*), prairie vole (*Microtus ochrogaster*), and meadow vole (*Microtus pennsylvanicus*). Only teeth were examined. *Synaptomys* teeth are distinct and easily separated from the other species. The M_1 of *M. pennsylvanicus* is diagnostic for specific identification. Previous faunal analysis of the Rodgers Shelter bone had indicated the presence of *M. pennsylvanicus* in the earlier horizons (Parmalee *et al.* 1976). Re-examination of that material, however, showed that the original identification was in error (Parmalee pers. comm.; Graham pers. comm.; Saunders pers. comm.). *M. pennsylvanicus*, therefore, is not present in Rodgers Shelter. All of the small microtine material, except for *Synaptomys*, represents *P. pinetorum* or *M. ochrogaster*. At present the two forms cannot be reliably separated.

Certain of the following analyses involves the number (raw counts or minimum number of individuals) of a particular taxon in a specified horizon. Because the volume of matrix removed per horizon differed either due to the nature of the horizon or excavation strategy, it was important to correct for the amount of matrix sampled. Table 9.2 lists the sampling effort by excavation and horizon. The volumes were based on the size of excavation holes after removal of the matrix. Unfortunately, sediment compaction was not considered due to a number of methodological problems. At any rate, both raw counts (E) of bone and minimum number of individual (MNI) are reported in terms of number per m^3 matrix removed (Table 9.3).

TABLE 9.2

Amount Matrix Processed for Fauna (units are in m^3)

Horizon	1974	1976 wt	1976 M	1974	1976 wt
				1976 M	1976 M
				Total	Total
1	0.704	3.696	0.176	0.880	4.576
2	0.704	0.704	0.352	1.056	1.760
3	1.172	0.704	0.528	1.700	2.404
4	0.485	2.288	1.232	1.717	4.005
5	0.417	2.288	2.288	2.705	4.993
6	0.181	0.528	0.880	1.061	1.589
7	0.087	0.704	0.704	0.791	1.495
8	0.000	2.640	1.584	1.584	4.224
9	0.000	0.000	2.288	2.288	2.288
10	0.000	2.447	3.520	3.520	5.967
11	0.000	0.080	0.000	0.000	0.080

TABLE 9.3

Summary of Faunal Remains

Horizon	Excavation	Number	Count		Total No/m ³	%
				No/m ³		
<u>Lepisosteidae:</u>						
1	1974	1	1.420			
	1976 wt	1	0.271	0.437	1.9	
2	1974	2	2.841			
	1976 M	7	19.886	5.114	22.3	
3	1976 wt	1	1.420			
	1976 M	2	3.788	1.248	5.4	
5	1976 M	22	9.615	4.406	19.2	
6	1976 M	11	12.500	6.923	30.2	
7	1976 M	3	4.261	2.007	8.8	
8	1976 wt	2	0.758			
	1976 M	6	3.788	1.894	8.3	
9	1976 M	2	0.874	0.874	3.8	
Totals		60		22.902	99.9	
<u>Castostomidae:</u>						
1	1974	35	49.716			
	1976 wt	3	0.812	8.304	4.3	
2	1974	25	35.511	14.205	7.4	
3	1974	7	5.973	2.912	1.5	
5	1976 wt	16	6.993			
	1976 M	326	142.483	68.496	35.5	
6	1976 M	113	128.409	71.114	36.8	
7	1974	2	22.989			
	1976 M	36	51.136	25.418	13.2	
8	1976 wt	2	0.758			
	1976 M	3	1.894	1.184	0.6	
9	1976 M	3	1.311	1.311	0.7	
10	1976 wt	1	0.409	0.168	0.1	
Totals		572	193.111		100.1	
<u>Moxostoma sp.</u>						
1	1974	14	19.886			
	1976 M	3	17.045	3.715	2.9	
2	1974	17	24.148			
	1976 M	7	19.886	13.636	10.5	
3	1974	8	6.826			
	1976 M	5	9.470	5.408	4.2	
4	1974	1	2.062	0.250	0.2	
5	1976 wt	12	5.245			
	1976 M	171	24.738	36.651	28.3	

TABLE 9.3 (continued).

Horizon	Excavation	Number	Count		Total No/m ³	%
			No/m ³			
<i>Moxostoma</i> sp. (continued):						
6	1976 M	59	67.045		37.130	28.7
7	1974	1	11.494			
	1976 M	40	56.818		27.425	21.2
8	1976 M	7	4.419		1.657	1.3
9	1976 M	8	3.497		3.497	2.7
10	1976 M	1	0.284		0.167	0.1
Totals		354	129.536			100.1
<i>Ictaluridae</i> :						
1	1974	11	15.625			
	1976 wt	4	1.082			
	1976 M	5	28.409		4.371	2.8
2	1974	8	11.364			
	1976 M	9	25.568		9.659	6.1
3	1974	11	9.386			
	1976	4	7.576		6.240	4.0
5	1974	1	2.398			
	1976 wt	9	3.934			
	1976 M	189	82.605		39.856	25.3
6	1974	2	11.050			
	1976 M	93	105.682		59.786	38.0
7	1974	3	34.483			
	1976 M	49	69.602		34.783	22.1
8	1976 wt	1	0.379			
	1976 M	7	4.419		1.894	1.2
9	1976 M	1	0.437		0.437	0.3
10	1976 wt	1	0.409			
	1976 M	1	0.284		0.335	0.2
Totals		409			157.360	100.0
<i>Centrarchidae</i> :						
1	1974	7	9.943		1.530	9.8
2	1974	13	18.466		7.386	47.3
3	1974	9	7.679			
	1976 M	1	1.894		4.160	26.6
5	1976 wt	2	0.874			
	1976 M	5	2.185		1.402	9.0
7	1976 M	1	1.420		0.669	4.3
8	1976 M	2	1.263		0.473	3.0
Totals		40			15.620	100.0

TABLE 9.3 (continued).

Horizon	Excavation	Number	Count		%
			No/m ³	Total No/m ³	
<i>Aplodinotus grunniens</i> :					
1	1976M	1	5.682	0.219	1.0
2	1976 M	1	2.841	0.568	2.6
5	1976 wt	1	0.437		
	1976 M	26	11.364	5.408	25.1
6	1976 M	11	12.500	6.923	32.1
7	1976 M	10	14.205	6.688	31.0
8	1976 M	3	1.894	0.710	3.3
9	1976 M	2	0.874	0.874	4.1
10	1976 M	1	0.284	0.168	0.8
Totals		56		21.558	100.0
<i>Herptiles (exclusive of Terrapene sp.):</i>					
1	1974	186	264.205		
	1976 wt	3	0.812		
	1976 M	44	250.000	50.918	8.8
2	1974	161	228.693		
	1976 M	76	215.909	134.659	23.2
3	1974	122	104.096		
	1976 wt	2	2.841		
	1976 M	57	107.955	75.291	13.0
4	1974	9	18.557		
	1976 M	3	2.435	2.996	0.5
5	1974	50	119.904		
	1976	91	39.773		
	1976 M	408	178.322	109.954	18.9
6	1974	19	104.972		
	1976 M	124	140.909	89.994	15.5
7	1974	4	45.977		
	1976 M	67	95.170	47.492	8.2
8	1976 wt	91	34.470		
	1976 M	79	49.874	40.246	6.9
9	1976 M	35	15.297	15.297	2.6
10	1976 wt	24	9.808		
	1976 M	59	16.761	13.910	2.4
Totals		1714		580.757	100.0
<i>Terrapene sp.:</i>					
1	1976 M	3	17.045	0.656	2.2
2	1976 M	3	8.523	1.705	5.8
3	1974	2	1.706		
	1976 M	2	3.788	1.664	5.6
4	1974	4	8.247		

TABLE 9.3 (continued).

Horizon	Excavation	No	Count		Total No/m ³	%	Element	MNI	MNI Determination		
			No/m ³						MNI/m ³	Total MNI/m ³	%
<i>Terrapene</i> sp. (continued):											
4	1976 M	2	1.623		1.498	5.1					
5	1976 M	49	21.416		9.814	33.1					
6	1976 M	10	11.364		6.293	21.2					
7	1976 M	11	15.625		7.358	24.8					
8	1976 M	2	1.263		0.473	1.6					
10	1976 M	1	0.284		0.168	0.6					
Totals		89			29.529	100.0					
Miscellaneous Birds:											
1	1974	23	32.670				Left coracoid	1	1.420		
	1976 M	4	22.727		5.900	8.9	Left ulna (p)	1	5.682	0.437	4.6
2	1974	35	49.716				Left tibiotarsus (d)	3	4.261		
	1976 M	4	11.364		22.159	33.4	Left humerus (d)	1	2.841	2.273	23.7
3	1974	41	34.983				Left femur (p)	4	3.413		
	1976 wt	1	1.420				Right tarsometatarsus(d)	1	1.420		
	1976 M	4	7.576		19.135	28.8	Right ulna (p)	1	1.894	2.496	26.0
4	1974	1	2.062		0.250	0.4	Bone fragment	1	2.063	0.250	2.6
5	1974	1	2.398				Metapodial	1	2.398		
	1976 wt	4	1.748				Left coracoid (d)	1	0.437		
	1976 M	34	14.860		7.811	11.8	Right tibiotarsus (d)	5	2.185	1.402	14.6
6	1976 M	7	13.258		4.405	6.6	Right tibiotarsus (d)	2	3.788	1.259	13.1
7	1976 M	6	8.523		4.013	6.0	Left ulna (d)	1	1.420	0.669	7.0
8	1976 wt	2	0.758				Right 1st phalanx	1	0.379		
	1976 M	3	1.894		1.184	1.8	Right humerus (p)	1	0.631	0.473	4.9
10	1976 wt	3	1.226				Left humerus (p)	1	0.409		
	1976 M	6	1.705		1.508	2.3	Left coracoid (d)	1	0.284	0.335	3.5
Totals		179			66.365	100.0		27		9.594	100.0

TABLE 9.3 (continued).

Horizon	Excavation	No	Count		Total No/m ³	%	Element	MNI Determination		
			No	No/m ³				MNI	MNI/m ³	Total MNI/m ³ %
<i>Meleagris gallopavo</i> :										
1	1974	2	2	2.841			Left tibiotarsus	1	1.420	
	1976	1	1	0.271	0.656	11.4	Metapodial	1	0.271	0.437 14.8
2	1974	3	3	2.560			Left coracoid (p)	2	2.841	
	1976 M	1	1	2.841	2.273	39.4	Left 1st phalanx	1	2.841	1.705 57.6
3	1974	2	2	1.706	0.832	14.4	Right scapula (d)	1	0.853	0.416 14.1
5	1976 wt	3	3	1.311			Left tarsometatarsus(p)	1	0.437	
	1976 M	7	7	3.059	2.003	34.8	Right humerus (d)	1	0.437	0.401 13.6
Totals		19			5.764	100.0		8		2.959 100.0
<i>Didelphis virginiana</i>										
1	1974	1	1	1.420	0.219	33.4	Right M ¹	1	1.420	0.219 33.4
5	1976 M	1	1	0.437	0.200	30.5	Bone fragment	1	0.437	0.200 30.5
8	1976 M	1	1	0.631	0.237	36.1	Left M ₁	1	0.631	0.237 36.1
Totals		3			0.656	100.0		3		0.656 100.0
<i>Scalopus aquaticus</i> :										
1	1974	10	10	14.205			Right mandible	2	2.841	
	1976 wt	18	18	4.870			Left M ¹	1	0.271	
	1976 M	23	23	130.682	11.145	12.4	Right M ₁	2	11.364	1.093 8.0
2	1974	7	7	9.943			Right M ₁	1	1.420	
	1976 wt	2	2	2.841			Right radius (p)	1	1.420	
	1976 M	14	14	39.773	13.068	14.5	Left M ₁	2	5.682	2.273 16.7
3	1974	8	8	6.826			Left M ₂	1	0.853	
	1976	19	19	35.985	11.231	12.5	Left mandible	2	3.788	1.248 9.2
4	1974	1	1	2.062	0.250	0.3	Left humerus (d)	1	2.062	0.250 1.8
5	1974	4	4	9.592			Right mandible	1	2.398	

TABLE 9.3 (continued).

Horizon	Excavation	No	Count		Total No/m ³	%	Element	MNI	MNI Determination		
			No	No/m ³					MNI/m ³	Total MNI/m ³	%
<i>Scalopus aquaticus</i> (continued):											
5	1976 wt	33	14.423				Right M ₃	3	1.311		
	1976 M	31	13.549		13.619	15.1	Left mandible	4	1.748	1.602	11.8
6	1974	1	5.525				Right M ₂	1	5.525		
	1976 M	22	25.000		14.475	16.1	Right ulna	3	3.409	2.517	18.5
7	1974	1	11.494				Right humerus (d)	1	11.494		
	1976 M	10	14.205		7.358	8.2	Left M ₂	2	2.841	2.007	14.7
8	1976 wt	7	2.652				Right M ₂	1	0.379		
	1976 M	49	30.934		13.258	14.7	Right M ₂	5	3.157	1.420	10.4
9	1976 M	9	3.934		3.934	4.4	Right ulna (p)	2	0.874	0.874	6.4
10	1976 wt	7	2.861				Right M ₂	1	0.409		
	1976 M	3	0.852		1.676	1.9	Left ulna (p)	1	0.284	0.335	2.5
Totals		279			89.987	100.0		38		13.619	100.0
<i>Caryptotis parva</i> :											
1	1974	1	1.420				Left mandible	1	1.420	0.219	6.7
2	1974	2	2.841				Right mandible	2	2.841	1.136	34.9
5	1976 M	1	0.437		0.200	4.2	Right mandible	1	0.437	0.200	6.1
6	1976 M	1	1.136		0.629	13.2	Left mandible	1	1.136	0.629	19.3
7	1976 M	2	2.841		1.338	28.1	Left mandible	1	1.420	0.669	20.5
8	1976 wt	1	0.379		0.237	5.0	Left mandible	1	0.379	0.237	7.3
10	1976 M	6	1.705		1.006	21.1	Left I ¹	1	0.284	0.168	5.2
Totals		14			4.765	100.0		8		3.258	100.0
<i>Blarina brevicauda</i> :											
1	1974	3	4.261				Right mandible	1	1.420		

TABLE 9.3 (continued).

Horizon	Excavation	No	Count		Total No/m ³	%	Element	MNI Determination			
			No	No/m ³				MNI	MNI/m ³	Total MNI/m ³	%
<i>Blarina brevicauda</i> (continued):											
1	1976 wt	19	5.141				Right mandible	6	1.623		
	1976 M	3	17.045		5.463	28.4	Left mandible	2	11.364	1.967	24.4
2	1974	2	2.841				Palate	1	1.421		
	1976 M	3	8.523		2.841	14.8	Right mandible	1	2.840	1.136	14.1
3	1974	3	2.560		1.248	6.5	Right humerus	2	1.706	0.832	10.3
5	1974	3	7.194				Left mandible	1	2.398		
	1976 wt	3	1.311				Right mandible	1	0.437		
	1976 M	4	1.748		2.003	10.4	Right mandible	2	0.874	0.801	9.9
6	1976 M	4	4.545		2.517	13.1	Right mandible	2	2.273	1.259	15.6
7	1976 wt	3	4.261		2.007	10.4	Right mandible	1	1.420	0.669	8.3
8	1976 M	4	2.525		0.947	4.9	Left mandible	2	1.263	0.473	5.9
9	1976 M	2	0.874		0.874	4.5	Left maxilla	1	0.437	0.437	5.4
10	1976 wt	4	1.635				Right maxilla	1	0.409		
	1976 M	4	1.136		1.341	7.0	Left I1	2	0.568	0.503	6.2
Totals		64			19.241	100.0		26		8.077	100.0
cf. <i>Myotis</i> sp.:											
1	1976 M	1	5.682		0.219	7.5	Left mandible, M3	1	5.682	0.219	11.7
2	1974	2	2.841		1.136	38.9	Left maxilla	1	1.420	0.568	30.3
3	1974	1	0.853		0.416	14.3	I1	1	0.853	0.416	22.2
5	1976 M	1	0.437		0.200	6.9	Left mandible	1	0.437	0.200	10.7
8	1976 M	4	2.525		0.947	32.5	Right mandible	2	1.263	0.473	25.2
Totals		9			2.918	100.1		6		1.876	100.1

TABLE 9.3 (continued).

Horizon	Excavation	No	Count		Total No/m ³	%	Element	MNI Determination		
			No	No/m ³				MNI	MNI/m ³	Total MNI/m ³ %
<i>Eptesicus fuscus</i> :										
1	1974	12	17.045		2.622	21.4	Left p ⁴	4	5.682	0.874 26.2
2	1974	11	15.625		6.250	51.1	Right mandible	2	2.841	1.136 34.1
3	1974	1	0.853		0.416	3.4	Right mandible	1	0.853	0.416 12.5
7	1976 M	3	4.261		2.007	16.4	Left M ¹	1	1.420	0.669 20.1
8	1976 M	4	2.525		0.947	7.7	Left M ¹	1	0.631	0.237 7.1
Totals		31			12.242	100.0		9		3.333 100.0
<i>Homo sapiens</i> :										
1	1974	1	1.420		0.219	0.2	Right M ²	1	1.420	0.219 18.2
2	1974	1	1.420		0.568	0.6	Deciduous molar	1	1.420	0.568 47.2
3	1974	225	191.980		93.594	99.2	Left I ₂	1	0.853	0.416 34.6
Totals		227			94.381	100.0		3		1.203 100.0
<i>Procyon lotor</i> :										
1	1974	10	14.205				Left C ¹	2	2.841	
	1976 wt	1	0.271		2.404	6.1	Right M ¹	1	0.271	0.656 11.2
2	1976 M	2	5.682		1.172	3.0	Left M ¹	1	2.841	0.568 9.9
3	1974	3	2.560		1.248	3.2	Left P ₂	1	0.853	0.416 7.1
5	1976 wt	2	0.874				Left P ₃	1	0.473	
	1976 M	30	13.112		6.409	16.3	Left I ₂	2	0.874	0.601 10.3
6	1974	1	5.525				Left P ₄	1	5.525	
	1976 M	30	34.091		19.509	49.7	Left P ₃	3	3.409	2.517 43.2
7	1976 M	10	14.205		6.689	17.0	Right P ₃	1	1.420	0.669 11.5
8	1976 M	7	4.419		1.657	4.2	Left P ₁	1	0.631	0.237 4.1
10	1976 M	1	0.284		0.168	0.4	Left P ₃	1	0.284	0.168 2.9
Totals		97			39.256	99.9		15		5.832 100.0

TABLE 9.3 (continued).

Horizon	Excavation	No	Count		Total No/m ³	%	Element	MNI Determination		
			No	No/m ³				MNI	MNI/m ³	Total MNI/m ³ %
<i>Mustela vison:</i>										
5	1976 M	5	2.184		1.001	80.9	Left C ¹	1	0.437	0.200 45.8
8	1976 M	1	0.631		0.237	19.1	Right C ₁	1	0.631	0.237 54.2
Totals		6			1.238	100.0		2		0.437 100.0
<i>Taxidea taxus:</i>										
7	1976 M	2	2.841		1.338	100.0	Left M ¹	1	1.420	0.669 100.0
<i>Spilogale putorius:</i>										
3	1974	2	1.706		0.832	28.4	Left C ¹	1	0.853	0.416 19.7
5	1976 M	4	1.748		0.801	27.3	Left M ₁	2	0.874	0.401 19.0
6	1976 M	1	1.136		0.629	21.5	Right M ₁	1	1.136	0.629 29.7
7	1976 M	1	1.420		0.669	22.8	Left ulna (p)	1	1.420	0.669 31.6
Totals		8			2.931	100.0		5		2.115 100.0
<i>Mephitis mephitis:</i>										
1	1974	2	2.841				Left mandible	1	1.420	
	1976 M	1	5.682		0.656	13.2	Left maxilla	1	5.682	0.437 15.2
2	1976 M	1	2.841		0.568	11.4	Right C ₁	1	2.841	0.568 19.7
3	1974	1	0.853		0.416	8.3	Left M ₁	1	0.853	0.416 14.4
5	1976 M	1	0.437		0.200	4.0	Right P ₃	1	0.437	0.200 6.9
6	1974	1	5.525				Left M ₁	1	5.525	
	1976 M	4	4.545		3.147	63.1	Left C ₁	1	1.136	1.259 43.7
Totals		11			4.987	100.0		7		2.880 99.9

TABLE 9.3 (continued).

Horizon	Excavation	No	Count		Total No/m ³	%	Element	MNI Determination			
			No/m ³	Total				MNI	MNI/m ³	Total MNI/m ³	%
<i>Canis</i> sp.:											
1	1976 wt	1	0.271				Left M ³	1	0.271		
	1976 M	2	11.364		0.656	1.9	Right I ²	1	5.682	0.437	8.8
2	1974	1	1.420				Left P ₄	1	1.420		
	1976 M	4	11.364		2.841	8.2	Right astragalus	1	2.841	1.136	22.9
3	1974	3	2.560		1.248	3.6	Left P ₄	1	0.853	0.416	8.4
5	1974	1	2.398				Right M ³	1	2.398		
	1086 wt	1	0.437				Right I ₁	1	0.437		
	1976 M	39	17.045		8.211	23.6	Right P ₄	2	0.874	0.801	16.2
6	1976 M	18	20.455		11.328	32.6	Right p ₁	2	2.273	1.259	25.4
7	1976 M	15	21.307		10.033	28.8	Right M ³	1	1.420	0.669	13.5
8	1976 M	2	1.263		0.473	1.4	Right P ₃ (cf)	1	0.631	0.237	4.8
Totals		87			34.790	100.0		13		4.955	100.0
<i>Urocyon cinereoargenteus</i> :											
5	1976 M	2	0.870		0.400	17.5	Left M ₃	1	0.437	0.200	24.1
6	1976 M	3	3.409		1.888	82.5	Left I ₃	1	1.136	0.629	75.9
Totals		5			2.288	100.0		2		0.829	100.0
<i>Vulpes fulva</i> :											
5	1976 M	1	0.437		0.200	2.3	Left I ₂	1	0.437	0.200	2.3
7	1976 M	1	0.587		0.669	7.7	Right P ₄	1	0.587	0.669	7.7
Totals		2			0.869	100.0		2		0.869	100.0

TABLE 9.3 (continued).

Horizon	Excavation	No	Count		Total No/m ³	%	Element	MNI Determination			
			No	No/m ³				MNI	MNI/m ³	Total MNI/m ³	%
<i>Tamias striatus:</i>											
1	1974	3	4.261				Left I ¹	1	1.420		
	1976 wt	2	0.541		1.093	6.7	Left I ¹	2	0.541	0.656	12.7
2	1974	3	4.261				Right I ¹	1	1.420		
	1976 M	2	5.682		2.841	17.5	Left I ¹	1	2.841	1.136	21.9
3	1974	13	11.092				Left mandible	2	1.706		
	1976 M	2	3.788		6.240	38.4	Left mandible	1	1.894	1.248	24.1
5	1976 M	7	3.059		1.402	8.6	Right I ¹	1	0.437	0.200	3.9
6	1976 M	1	1.136		0.629	3.9	Right I ¹	1	1.136	0.629	12.1
7	1976 M	4	5.682		2.676	16.5	Left I ¹	1	1.420	0.669	12.9
8	1976 wt	1	0.379				Left I ¹	1	0.379		
	1976 M	4	2.525		1.184	7.3	Left I ¹	1	0.631	0.473	9.1
10	1976 M	1	0.284		0.168	1.0	Left I ¹	1	0.284	0.168	3.2
Totals		43			16.231	99.9		14		5.179	99.9
<i>Marmota monax:</i>											
1	1974	4	5.682				Left ulna (p)	1	1.420		
	1976 wt	1	0.271		1.093	20.6	Right M ¹	1	0.271	0.437	36.3
2	1974	6	8.523		3.409	64.3	Right P ⁴	1	1.420	0.568	47.1
5	1976 M	4	1.748		0.801	15.1	Left I ¹	1	0.437	0.200	16.6
Totals		15			5.303	100.0		4		1.205	100.0
Small Squirrels:											
<i>Spermophilus franklini</i>											
1	1976 M	1	5.682		0.219	4.5	Right I ¹ (cf)	1	5.682	0.219	12.8
5	1976 wt	1	0.437		0.200	4.1	Right tibia (d)	1	0.437	0.200	11.6
6	1976 M	5	5.682		3.147	64.2	Left I ¹	1	1.136	0.629	36.6

TABLE 9.3 (continued).

Horizon	Excavation	No	Count		Total No/m ³	%	Element	MNI Determination		
			No	No/m ³				MNI	MNI/m ³	Total MNI/m ³ %
<i>Spermophilus franklini</i> (continued)										
7	1976 M	2	2	2.841	1.338	27.3	Right I ¹	1	1.420	0.669 39.0
Totals		9			4.904	100.0		4		1.717 100.0
<i>Spermophilus tridecemlineatus</i>										
10	1976 M	2	2	0.568	0.335	100.0	Left I ¹ (cf)	1	0.284	0.168 100.0
<i>Glaucomys volans</i>										
6	1976 M	1	1	1.136	0.629	100.0	Right mandible	1	1.136	0.629 100.0
<i>Sciurus</i> spp.:										
1	1974	15	15	21.307			Left I ¹	2	2.841	
	1976 wt	45	45	12.175			Right P ⁴	3	0.812	
	1976 M	21	21	119.318			Right I ¹	2	11.364	
2	1974 + 1976 M	36	36	40.909	17.701	1.6	Right I ¹	3	3.409	1.093 2.1
	1974	25	25	35.511			Left astragalus	6	8.523	
	1976 M	27	27	76.705			Left humerus (d)	3	8.523	
3	1974 + 1976 M	52	52	49.242	29.545	2.7	Left astragalus	7	6.629	5.114 10.0
	1974	24	24	20.478			Right I ¹	3	2.560	
	1976 wt	18	18	11.364			Left astragalus	2	2.841	
4	1976 M	13	13	24.621			Right M ₂	2	3.788	
	1974 + 1976 M	47	47	22.647	18.719	1.7	Right I ¹	3	1.765	1.664 3.2
	1974	3	3	6.186			Left I ¹	1	2.062	
5	1976 M	3	3	2.435			Right mandible	2	1.623	
	1974 + 1976 M	6	6	3.494	1.498	0.1	Right mandible	2	1.165	0.499 1.0
	1974	16	16	38.369			Left M ₁	2	4.796	

TABLE 9.3 (continued).

Horizon	Excavation	No	Count		Total No/m ³	%	Element	MNI Determination		
			No	No/m ³				MNI	MNI/m ³	Total MNI/m ³ %
<i>Sciurus</i> spp. (continued):										
5	1976 wt	114	49.825				Right I ¹	7	3.059	
	1976 M	988	431.818				Right I ¹	33	14.423	
	1974 + 1976 M	1004	371.165		223.913	20.4	Right I ¹	33	12.200	8.412 16.4
	1974	12	66.298				Right calcaneum	4	22.099	
6	1976 M	914	1038.636				Left I ¹	33	37.500	
	1974 + 1976 M	926	872.762		582.756	53.0	Left I ¹	34	32.045	23.285 45.3
7	1974	6	68.966				Right calcaneum	2	22.989	
	1976 M	283	401.989				Left M ₃	12	17.045	
	1974 + 1976 M	289	365.360		193.311	17.6	Left M ₃	12	15.171	8.027 15.6
	1976 wt	2	0.758				Right M ₃	1	0.379	
8	1976 M	92	58.081		22.254	2.0	Right I ¹	6	3.788	1.657 3.2
	1976 M	22	9.615		9.615	0.9	Right M ₁	3	1.311	1.311 2.6
10	1976 wt	3	1.226				Right fibula (d)	1	0.409	
	1976 M	3	0.852		1.006	0.1	Right P ₃	1	0.284	0.335 0.7
Totals		2639			1100.319	100.0		121		51.397 100.0
<i>Geomys bursarius</i> :										
1	1974	2	2.841				Right P ⁴	1	1.420	
	1976 wt	9	12.784				Right P ⁴	3	0.812	
	1976 M	6	34.091		3.715	6.5	Premaxilla	1	5.682	1.093 13.3
	1974	12	17.045				Premaxilla	1	1.420	
2	1976 M	20	56.818		18.182	31.9	Left P ⁴	2	5.682	1.705 20.7
	1974	5	4.266				Left I ¹	1	0.853	
3	1976 wt	3	4.261				Left P ⁴	1	1.420	
	1976 M	10	18.939		7.488	13.1	Left I ¹	1	1.894	1.248 15.1
4	1974	1	2.062				Molar fragment	1	2.062	

TABLE 9.3 (continued).

Horizon	Excavation	No	Count		Total No/m ³	%	Element	MNI	MNI Determination		%
			No	No/m ³					MNI/m ³	Total MNI/m ³	
<i>Geomys bursarius</i> (continued):											
4	1976 M	1	0.812		0.499	0.9	Molar	1	0.812	0.499	6.1
5	1974	5	11.990				Left I ₁	1	2.398		
	1976 wt	4	1.748				Left P ₄	1	0.437		
	1976 M	97	42.395		21.230	37.3	Right P ₄	6	2.622	1.602	19.4
6	1976 M	8	9.091		5.035	8.8	Right P ₄	2	2.273	1.259	15.3
7	1976 M	1	1.420		0.669	1.2	Right radius (p)	1	1.420	0.669	8.1
10	1976 M	1	0.284		0.168	0.3	Molar	1	0.284	0.168	2.0
Totals		185			56.985	100.0		25		8.242	100.0
<i>Peromyscus</i> spp.:											
1	1974	11	15.625				Right mandible	3	4.261		
	1976 wt	13	3.518		5.245	6.1	Left mandible	4	1.082	1.530	5.6
2	1974	16	22.727				Left mandible	5	7.102		
	1976 M	4	5.682		11.364	13.2	Right mandible	3	4.261	4.545	16.6
3	1974	5	4.266				Right I ₁	1	0.853		
	1976 M	1	1.894		2.496	2.9	Left maxilla, M ²	1	1.894	0.832	3.0
4	1974	1	2.062		0.250	0.3	Right I ₁	1	2.062	0.250	0.9
5	1974	1	2.398				Right I ₁	1	2.398		
	1976 wt	9	3.934				Right mandible	4	1.748		
	1976 M	41	17.920		10.214	11.9	Right I ₁	8	3.497	2.604	9.5
6	1974	1	5.525				Right I ₁	1	5.525		
	1976 M	21	23.864		13.845	16.1	Left I ₁	6	6.818	4.405	16.1
7	1974	3	34.483				Right I ₁	1	11.494		
	1976 M	29	41.193		21.405	24.9	Right I ₁	9	12.784	6.689	24.4
8	1976 wt	21	7.955				Left mandible	8	3.030		
	1976 M	36	22.727		13.494	15.7	Right I ₁	9	5.682	4.025	14.7

TABLE 9.3 (continued).

Horizon	Excavation	No	Count		Total No/m ³	%	Element	MNI Determination		
			No	No/m ³				MNI	MNI/m ³	Total MNI/m ³ %
<i>Peromyscus</i> spp. (continued):										
9	1976 M	2	0.874	0.874	1.0	Left I ₁	2	0.874	0.874	3.2
10	1976 wt	7	2.861			Right maxilla	2	0.817		
	1976 M	33	9.375			Left M ₁	8	2.273	1.676	6.1
11	1976 M	3				Left mandible	1			
Totals		258					78*		27.430*	100.1*
		255*								
<i>Neotoma floridana</i> :										
1	1974	3	4.261			Right M ³	1	1.420		
	1976 wt	25	6.764			Left M ₁	4	1.082		
	1976 M	6	34.091			Left M ₂	1	5.682	1.311	6.7
2	1974	5	7.102			Left calcaneum	2	2.841		
	1976 wt	1	1.420			Molar fragment	1	1.420		
	1976 M	10	28.409			Right M ₃	1	2.841	2.273	11.7
3	1974	4	3.413			Left maxilla	1	0.853		
	1976 wt	4	5.682			Left M ₁	2	2.841		
	1976 M	7	13.258			Right M ₃	2	3.788	2.080	10.7
4	1974	1	2.062			Right M ₁	1	2.062	0.250	1.3
5	1974	1	2.398			Right M ₂	1	2.398		
	1976 wt	10	4.371			Might M ₂	2	0.874		
	1976 M	73	31.906			Right M ₂	8	3.497	2.203	11.3
6	1974	2	11.050			Right M ₂	1	5.525		
	1976 M	94	106.818			Left M ₁	10	11.364	6.923	35.6
7	1974	3	34.483			Left M ₂	1	11.494		
	1976 M	29	41.193			Left M ₁	4	5.682	3.344	17.2

* Exclusive of Horizon 11

* Exclusive of Horizon 11

TABLE 9.3 (continued).

Horizon	Excavation	No	Count		Element	%	Total No/m ³	MNI Determination		
			No	No/m ³				MNI	MNI/m ³	Total MNI/m ³ %
<i>Neotoma floridana</i> (continued):										
8	1976 wt	4	1.515		Left M ¹			1	0.379	
	1976 M	3	1.894		Left M ¹	1.3	1.657	1	0.631	0.473 2.4
9	1976 M	6	2.622		Left M ¹	2.1	2.622	1	0.437	0.437 2.2
10	1976 M	4	1.136		Left M ¹	0.2	0.190	1	0.284	0.168 0.9
Totals		295				100.0	126.124	47		19.462 100.0
<i>Castor canadensis</i> :										
1	1974	1	1.420		Right M ¹			1	1.420	
	1976 M	1	5.682		Right M ¹	5.6	0.437	1	5.682	0.437 12.1
2	1976 M	1	2.841		Left M ³	7.2	0.568	1	2.841	0.568 15.7
3	1974	1	0.853		Molar	5.3	0.416	1	0.853	0.416 11.5
4	1976 M	1	0.812		Right M ¹	3.2	0.250	1	0.812	0.250 6.9
5	1976 wt	1	0.437		Left M ³			1	0.437	
	1976 M	1	0.437		Left humerus (d)	5.1	0.401	1	0.437	0.401 11.1
6	1976 M	1	1.136		Molar	8.0	0.629	1	1.136	0.629 17.4
7	1976 M	7	9.943		Left I ₁	59.6	4.682	1	1.420	0.669 18.5
8	1976 M	2	1.263		Vertebrae pads	6.0	0.473	1	0.631	0.237 6.6
Totals		17				100.0	7.856	10		3.607 99.8
<i>Synaptomys cooperi</i> :										
1	1974	3	4.261		Right M ¹			2	2.841	
	1976 wt	2	0.541		Right M ¹	4.9	1.093	1	0.271	0.656 8.7
2	1974	6	8.523		Left I ₁			2	2.841	
	1976 M	2	5.682		Left M ₁	20.4	4.545	1	2.841	1.705 22.6
3	1976 M	1	1.894		Right M ¹	1.9	0.416	1	1.894	0.416 5.5

TABLE 9.3 (continued).

Horizon	Excavation	No	Count		Total No/m ³	%	Element	MNI Determination		
			No	No/m ³				MNI	MNI/m ³	Total MNI/m ³ %
<i>Synaptomys cooperi</i> (continued):										
5	1976 wt	5	2.185				Left M ₁	2	0.874	
	1976 M	4	1.748		1.803	8.1	Right I ₁	2	0.874	0.801 10.6
7	1976 M	10	14.205		6.689	30.1	Right M ₁	3	4.261	2.007 26.6
8	1976 wt	4	1.515				Left I ₁	1	0.379	
9	1976 M	21	13.258		5.919	26.6	Left I ₁	4	2.525	1.184 15.7
	1976 M	1	0.437		0.437	2.0	Left M ₁	1	0.437	0.437 5.8
10	1976 M	8	2.273		1.341	6.0	Right M ₁	2	0.568	0.335 4.4
11	1976 M	2					Left M ₁	1		
Totals		69			47.243	100.0		23	20.041	100.0
					22.243*				7.541*	
<i>Microtus orchrogaster/Pitymys pinetorum</i> :										
1	1974	12	17.045				Left M ₂	3	4.261	
	1976 wt	50	13.528				Left M ₁	14	3.788	
2	1976 M	11	62.500		15.953	6.5	Right M ₁	3	17.045	4.371 8.9
	1974	32	45.455				Left M ₁	6	8.523	
3	1976 wt	2	2.841				Left M ₁	1	1.420	
	1976 M	27	76.705		34.659	14.0	Left M ₁	7	19.886	7.955 16.2
4	1974	12	10.239				Right M ₁	2	1.706	
	1976 wt	8	11.364				Left M ₁	4	5.682	
5	1976 M	21	39.773		17.055	6.9	Right M ₁	5	9.470	4.576 9.3
	1976 M	2	1.623		0.499	0.2	Right I ₁	1	0.812	0.250 0.5
6	1974	4	9.592				Left M ₁	2	4.796	
	1976 wt	55	24.038				Left M ₁	17	7.430	
7	1976 M	190	83.042		49.870	20.2	Right M ₁	34	14.860	10.615 21.6
	1974	1	5.525				Left M ₂	1	5.525	

TABLE 9.3 (continued).

Horizon	Excavation	No	Count		Element	%	Total No/m ³	MNI Determination		
			No	No/m ³				MNI	MNI/m ³	Total MNI/m ³ %
<i>Microtus orchrogaster/Pitymys pinetorum</i> (continued):										
6	1976 wt	3	5.682		Left I ¹			2	3.788	
	1976 M	60	68.182		Left M ₁	16.3	40.277	10	11.364	8.181 16.7
7	1976 wt	3	4.261		Left M ₁			1	1.420	
	1976 M	54	76.705		Left M ₁	15.4	38.127	6	8.523	4.682 9.5
8	1976 wt	34	12.879		Right M ₁			7	2.652	
	1976 M	92	58.081		Right M ₁	12.1	29.830	14	8.838	4.972 10.1
9	1976 M	8	3.497		Right M ₁	1.4	3.497	3	1.311	1.311 2.7
10	1976 wt	17	6.947		Right M ₁			3	1.226	
	1976 M	86	24.432		Left M ₁	7.0	17.262	10	2.841	2.179 4.4
11	1976 M	6			Right M ₂			2		
Totals		789						158		
		783*					247.029*100.0*	156*		49.092* 100.0*
<i>Ondatra zibethica</i> :										
3	1974	1	0.853		Left mandible			1	0.853	0.416 67.5
5	1976 M	3	1.311		Right lower molar			1	0.437	0.200 32.5
Totals		4					1.017 100.0	2		0.616 100.0
<i>Sylvilagus floridanus</i> :										
1	1974	19	26.989		Left astragalus			3	4.261	
	1976 wt	47	12.716		Left I ₁			3	0.812	
	1976 M	50	284.091		Right humerus	1.4	25.350	5	28.409	2.404 4.1
2	1974	26	36.932		Left tibia (d)			2	2.841	
	1976 wt	1	1.420		Patella			1	1.420	
	1976 M	34	96.591		Left I ₁	2.0	34.659	1.	2.841	2.273 3.9

TABLE 9.3 (continued).

Horizon	Excavation	No	Count		Total No/m ³	%	Element	MNI Determination			
			No	No/m ³				MNI	MNI/m ³	Total MNI/m ³	%
<i>Sylvilagus floridanus</i> (continued):											
3	1974	67	57.167				Right astragalus	4	3.413		
	1976 M	32	60.606		41.181	2.3	Right mandible	2	3.788	2.496	4.3
4	1974	14	28.866		3.496	0.2	Right calcaneum	2	4.124	0.499	0.9
5	1974	74	177.458				Left astragalus	6	14.388		
	1976 wt	274	119.755				Left I1	9	3.934		
	1976 M	1946	850.524		459.443	26.1	Left P3	43	18.794	11.616	19.8
6	1974	41	226.519				Left calcaneum	4	22.099		
	1976 M	1238	1406.818		804.909	45.7	Right I1	39	44.318	27.061	46.1
7	1974	23	264.368				Right P3	2	22.989		
	1976 wt	2	2.841				Right tibia (d)	1	1.420		
	1976 M	478	678.977		336.455	19.1	Right astragalus	12	17.045	10.033	17.1
8	1976 wt	9	3.409		40.009	2.3	Left P3	1	0.379	1.420	2.4
	1976 M	160	101.010		17.045	1.0	Left P3	5	3.157	0.874	1.5
9	1976 M	39	17.045				Left P3	2	0.874		
Totals		4574			1762.547	100.1		147		58.676	100.1
<i>Odocoileus virginianus</i> :											
1	1974	30	42.614				Left M3	1	1.420		
	1976 M	3	17.045				Molar fragment	1	5.682		
	1976 wt	12	3.247		9.834	9.1	Right I1 (deciduous)	1	0.271	0.437	8.4
2	1974	38	53.977				Right I1	1	1.420		
	1976 M	6	17.045				Right P3	1	2.841		
	1976 wt	1	1.420		25.568	23.8	Enamel fragment	1	1.420	1.136	21.9
3	1974	17	14.505				Right M3	1	0.853		
	1976 M	5	9.470		9.151	8.5	Right cuboid	1	1.894	0.416	8.0
4	1974	1	2.062				Metapodial	1	2.062		
	1976 M	2	1.623		0.749	0.7	Metacarpel fragment	1	0.812	0.250	4.8

TABLE 9.3 (concluded).

Horizon	Excavation	No	Count		Total No/m ³	%	Element	MNI Determination			
			No	No/m ³				MNI	MNI/m ³	Total MNI/m ³	%
<i>Odocoileus virginianus</i> (continued):											
5	1974	4		9.592			Tooth fragment	1	2.398		
	1976 M	133		58.129			Right metacarpel (p)	4	1.748		
	1976 wt	4		1.748	28.240	26.3	Left I ₃	1	0.437	1.001	
6	1974	3		16.575			Right greater cuneiform	1	5.525	19.3	
	1976 M	26		29.545	18.250	17.0	Left P ₂	1	1.136	12.1	
7	1974	1		11.494			Sesmoid	1	11.494		
	1976 M	17		24.148	12.040	11.2	Right M ¹	1	1.420	12.9	
8	1976 M	15		9.470	3.551	3.3	Left P ₂	2	1.263	9.1	
10	1976 wt	1		0.409	0.168	0.2	Left antler	1	0.409	3.2	
Totals		319			107.551	100.1		16		5.179	100.0
<i>Bison bison</i> :											
7	M	1		1.420	0.669	100.0	Right mandible	1	1.420	0.669	100.0

MNI's were determined by standard procedures: most common single element per horizon per excavation. The 1974 and 1976 main excavations were considered as one for calculation of MNI for medium and large animals. Identical analyses for depositional characteristics were run on E and MNI and are so reported. Calculations on clinal variation were initially conducted for both E and MNI. Parallel findings resulted; only data based on E are presented because of their greater statistical validity.

Multivariate analyses were used on several data sets. The specifics of each test will be presented later but, generally, *Statistical Package for the Social Sciences* (Nie *et al.* 1975) was used. Factor analyses were run using principal factoring without iteration and Varimax rotation. The option for factor scores was exercised (Kim 1975). For discriminant function analyses (Klecka 1975) the stepwise method based on Mahalanobis distance was utilized. Among the options selected was one that caused discriminant scores and classification information to be printed; these data were important in subsequent analysis of geographic variation.

RESULTS

A total of 13,557 specimens were identified into forty-one taxa. Data are summarized in Table 9.3 where total counts and MNI are listed by excavation and horizon. Among the fish, the suckers, identified as Castostomidae or *Moxostoma* sp., were most common. The mammal recovered in greatest number was the eastern cottontail, *Sylvilagus floridanus* (4,574 identified elements), followed by squirrels, *Sciurus* sp. (2,639). *Odocoileus virginianus* was the most common large mammal found in the excavations. The horizon with the greatest amount of bone was Horizon 6 with lesser amounts recovered in 5 and 7 (Fig. 9.2). A small peak was present in Horizon 2. Very little bone occurred in Horizons 4, 9, and 10. Horizon 11 was inadequately sampled (Table 9.2) and will not be further considered.

Patterns of Deposition. Since recovery techniques were similar from top to bottom in the 1974 and the two 1976 excavations, these data are suitable for studying patterns of bone deposition. Factor analysis was used to summarize these patterns. Variables included depositional density of all taxa with $E \geq 10$. Thus, factor analysis based on E had 28 variables and that based on MNI had 19. The difference between the two resulted from the deletion of taxa for which no MNI was determined, e.g., miscellaneous birds. Twenty-five cases were assigned, one for each horizon-excavation combination that had matrix volume $\geq 0.1\text{m}^3$ (Table 9.2).

Rotated factor scores for the factor analysis based on E are graphically presented in Figure 9.3. (Five unrotated factors having eigenvalues greater than 1.0 accounting for 89.7% of the total variation were orthogonally rotated.) The fauna from excavations on the west terrace had no discernable pattern on any of the factors, indicating random, low-level bone deposition. Likewise, neither Horizons 4 nor 9, when considered on a site-wide basis, fit into one of the overall patterns.

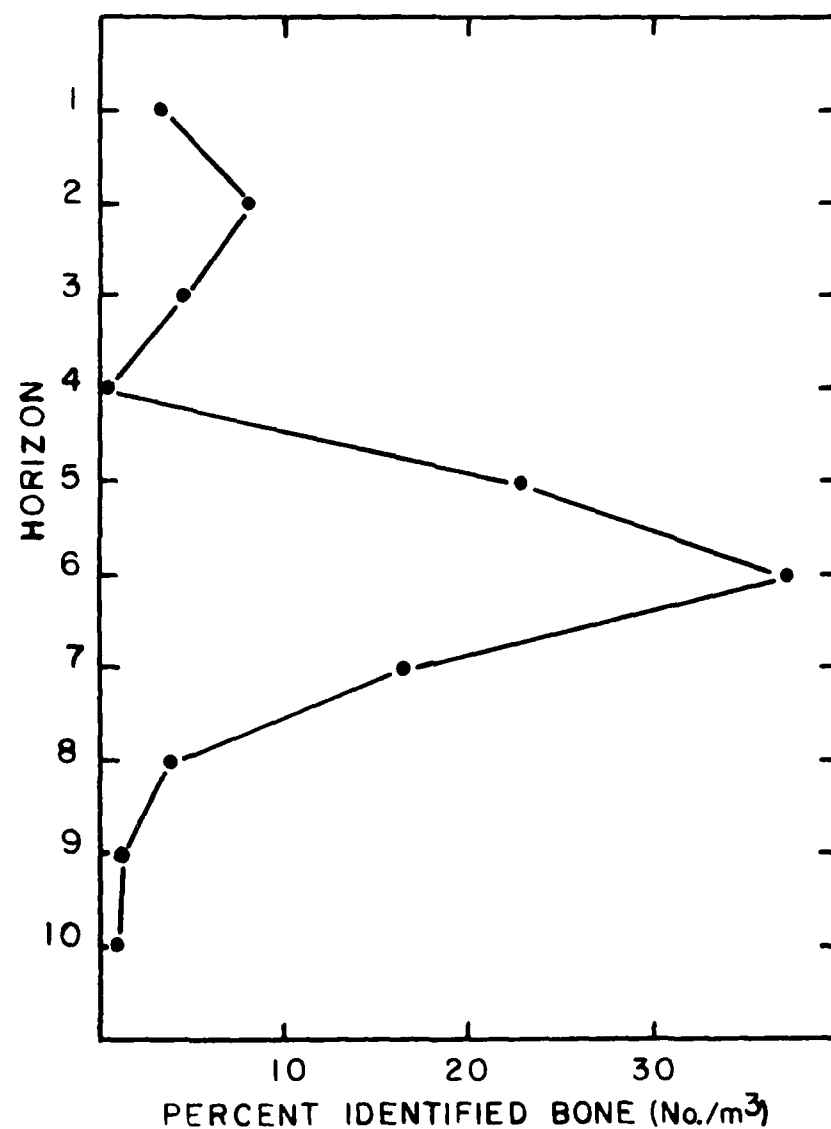


Figure 9.2. Density of identified bone from Rodgers Shelter (all three excavations).

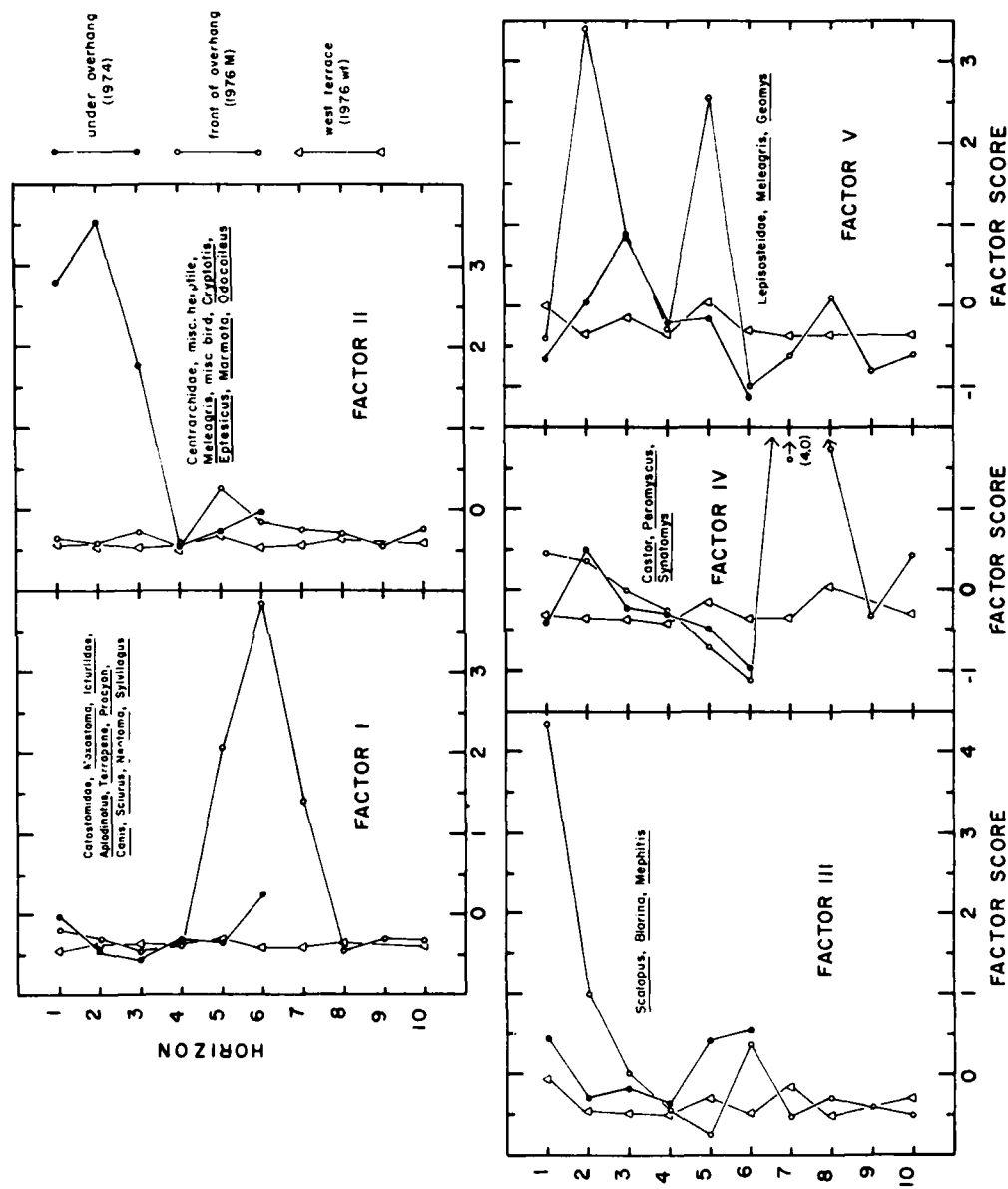


Figure 9.3. Factor scores for E-based factor analysis. Listed taxa had loadings of ≤ 0.6 for the indicated factors (Table 9.3).

Factor I indicated heavy deposition of fish, *Terrapene* sp., and medium-sized mammals in front of the overhang in Horizons 5, 6, and 7 (Fig. 9.3). These taxa were positively loaded on Factor I (Table 9.4).

TABLE 9.4

Correlations of Original Variables with Principal Factors

Species	Principal Factor				
	I	II	III	IV	V
Lepisosteidae	0.54	0.02	0.10	0.08	0.68
Catostomidae	0.90	0.30	-0.09	-0.04	0.19
<i>Moxostoma</i> sp.	0.88	0.23	0.05	0.23	0.29
Ictaluridae	0.95	0.08	0.13	0.17	0.19
Centrarchidae	-0.08	0.96	-0.05	0.09	0.06
<i>Aplodinotus grunniens</i>	0.87	-0.07	0.14	0.41	0.15
<i>Terrapene</i> sp.	0.65	-0.09	0.38	0.29	0.38
misc. herptile	0.29	0.63	0.58	0.09	0.34
<i>Meleagris gallopavo</i>	0.10	0.68	0.01	-0.07	0.66
misc. bird	0.11	0.86	0.28	0.08	0.19
<i>Scalopus aquaticus</i>	0.09	-0.04	0.92	0.20	0.15
<i>Cryptotis parva</i>	0.35	0.61	-0.13	0.54	-0.18
<i>Blarina brevicauda</i>	0.03	0.06	0.90	0.01	0.19
<i>Eptesicus fuscus</i>	-0.03	0.94	0.00	0.20	-0.11
<i>Procyon lotor</i>	0.92	0.18	0.04	0.04	-0.01
<i>Mephitis mephitis</i>	0.39	0.11	0.75	-0.19	-0.08
<i>Canis latrans/familiaris</i>	0.82	-0.04	0.26	0.37	0.28
<i>Marmota monax</i>	-0.01	0.96	-0.02	0.01	0.02
<i>Tamias striatus</i>	0.08	0.46	-0.03	0.35	0.48
<i>Sciurus carolinensis/niger</i>	0.98	-0.01	0.08	0.04	0.00
<i>Geomys bursarius</i>	0.19	0.08	0.48	-0.01	0.81
<i>Castor canadensis</i>	0.30	-0.04	0.41	0.79	0.02
<i>Peromyscus</i> sp.	0.59	0.39	-0.15	0.65	-0.01
<i>Neotoma floridana</i>	0.91	-0.03	0.30	0.06	0.05
<i>Synaptomys cooperi</i>	0.09	0.31	-0.11	0.86	0.14
<i>Microtus ochrogaster/</i> <i>Pitymys pinetorum</i>	0.58	0.13	0.31	0.48	0.49
<i>Sylvilagus floridanus</i>	0.98	-0.02	0.11	0.07	0.05
<i>Odocoileus virginianus</i>	0.51	0.74	0.13	0.08	0.31
Unrotated Percent of Variation	46.60	19.10	11.50	7.10	5.40
Cumulative percent of Variation	46.60	65.70	77.20	84.30	89.70

A smaller, contemporaneous peak occurred under the overhang. Most likely the taxa in Horizons 5 to 7 were there as a result of cultural activity. The conclusion is enhanced by examination of burned bone (Table 9.5). Most of the taxa had burning rates between ten and thirty percent. I am assuming, with reservations, that the majority of burned

TABLE 9.5

Percentages of Burned Bone for Taxa With High Loadings
in the E Factor Analysis

Taxon	Horizon				
A. Percent burned in Horizons 5, 6 and 7 for taxa loaded high on					
Factor I.	<u>5</u>	<u>6</u>	<u>7</u>		
Castostomidae	9.9	10.6	5.3		
<i>Moxostoma</i>	6.6	6.8	2.4		
Ictaluridae	23.1	22.1	13.5		
<i>Aplodinotus grunniens</i>	18.5	27.3	30.0		
<i>Terrapene</i>	36.7	34.5	0.0		
<i>Procyon lotor</i>	31.3	6.5	10.0		
<i>Canis latrans/familiaris</i>	14.6	11.1	6.7		
<i>Sciurus carolinensis/niger</i>	16.3	15.0	20.4		
<i>Neotoma floridana</i>	15.5	13.5	12.5		
<i>Sylvilagus floridanus</i>	19.3	21.3	21.3		
B. Percent burned in Horizons 1, 2 and 3 for taxa highly loaded on					
Factor II.	<u>1</u>	<u>2</u>	<u>3</u>		
Centrarchidae	0.0	7.7	0.0		
misc. herptile	19.3	17.3	23.8		
<i>Meleagris gallopavo</i>	66.7	25.0	100.0		
misc. bird	33.3	59.3	58.7		
<i>Cryptotis parva</i>	0.0	0.0	---		
<i>Eptesicus fuscus</i>	8.3	0.0	0.0		
<i>Marmota monax</i>	20.0	83.3	---		
<i>Odocoileus virginianus</i>	48.9	68.9	63.6		
C. Percent burned bone in Horizons 1, 2 and 3 for taxa highly loaded					
on Factor III.	<u>1</u>	<u>2</u>	<u>3</u>		
<i>Scalopus aquaticus</i>	1.9	0.0	22.2		
<i>Blarina brevicauda</i>	4.0	0.0	0.0		
<i>Mephitis mephitis</i>	33.0	100.0	100.0		
D. Percent burned bone in Horizons 1, 2, 7, 8 and 10 for taxa highly					
loaded on Factor IV.	<u>1</u>	<u>2</u>	<u>7</u>	<u>8</u>	<u>10</u>
<i>Castor canadensis</i>	50.0	0.0	0.0	0.0	---
<i>Peromyscus</i> sp.	0.0	5.0	0.0	1.8	0.0
<i>Synaptomys cooperi</i>	20.0	0.0	0.0	0.0	12.5

bone resulted from cultural activities. Obviously there are other, non-cultural, reasons--e.g., forest fire--why bone might be found burned, but these alternatives would be rare relative to the burn frequency generated from daily food preparations by prehistoric humans. Presence of unburned bone, however, may be due to either cultural or natural deposition. The probability is therefore high that burned bone, considered along with species size and abundance, is indicative of cultural usage.

In contrast to Factor I, Factor II represents a mixture of cultural and natural deposition. Factor II peaks under the overhang in Horizons 1, 2 and 3. A lesser peak occurs in Horizon 5 in front of the overhang (Fig. 9.3). All taxa with high loading values are positive (Table 9.4). The big brown bat, *Eptesicus fuscus*, and least shrew, *Cryptotis parva*, were probably present as a result of natural processes, as evidenced by small body sizes and low rates of burning (Table 9.5). *Meleagris gallopavo* (turkey), *Marmota monax* (woodchuck), and *Odocoileus virginianus* (white-tailed deer), showed high frequencies of burning, indicating cultural deposition. Centrarchids (bass and sunfish) bones showed little burning, but were most likely present due to cultural agents, unless they were deposited by some extraordinary, undetected natural reason. Miscellaneous herptiles and birds had high burn rates, but because of the heterogeneous taxonomic nature of the groups, little can be said of them.

Factor III had a major peak in Horizons 1 and 2 in front of the overhang along with a small peak in Horizon 6 (under and in front of the overhang). It appears that this is a natural pattern of deposition in part because two of three species with high positive loadings (Table 9.4) have low burn rates (Table 9.5). The eastern mole, *Scalopus aquaticus*, and short-tailed shrew, *Blarina brevicauda*, are small, burrowing mammals that probably lived on the site. Because of these factors one would suspect that their presence in the site deposits was the result of nonculturally induced mortality. The third species striped skunk (*Mephitis mephitis*), may or may not have been culturally deposited. Burn rates are high (Table 9.5) but sample size is low (Table 9.3); what specimens are present follow the same depositional pattern as *Scalopus* and *Blarina*.

The effect of the Hypsithermal is apparent in Favor IV (Fig. 9.3). The deposits in the main excavation indicate a positive peak in the presence of beaver (*Castor canadensis*), deer mouse (*Peromyscus* sp.) and bog lemming (*Synaptomys cooperi*) in Horizons 7, 8 and 10. A negative peak occurs in the horizons laid down during the Hypsithermal (5-6). Finally in Horizons 1 and 2 the pattern becomes slightly positive once again. Deposits from under the overhang are similar down through Horizon 6, where the 1974 excavation was terminated. *Castor* and *Synaptomys* are both associated with aquatic or moist habitats. Because specific identifications were not made on *Peromyscus*, habitat interpretation is not appropriate. In most instance, the burn rates are low (Table 9.5), indicating probable non-cultural mortality. *Castor*, because of its large size, may be an exception and probably represents cultural deposition.

Factor V is not readily interpretable. Gar, turkey, and gopher are thrown together in a depositional pattern that is sporadic (Table 9.4, Fig. 9.3). Very little variation is accounted for by the factor; therefore it will be ignored.

A comparable factor analysis was done based on MNI. The number of cases (25) was identical to the previous analysis; however, the number of variables was reduced to 19 due to the deletion of those taxa for which MNI was not determined. The results are shown in Figure 9.4 and loadings of original variables are listed in Table 9.6. Five unrotated factors were extracted with eigenvalues greater than 1.0 explaining

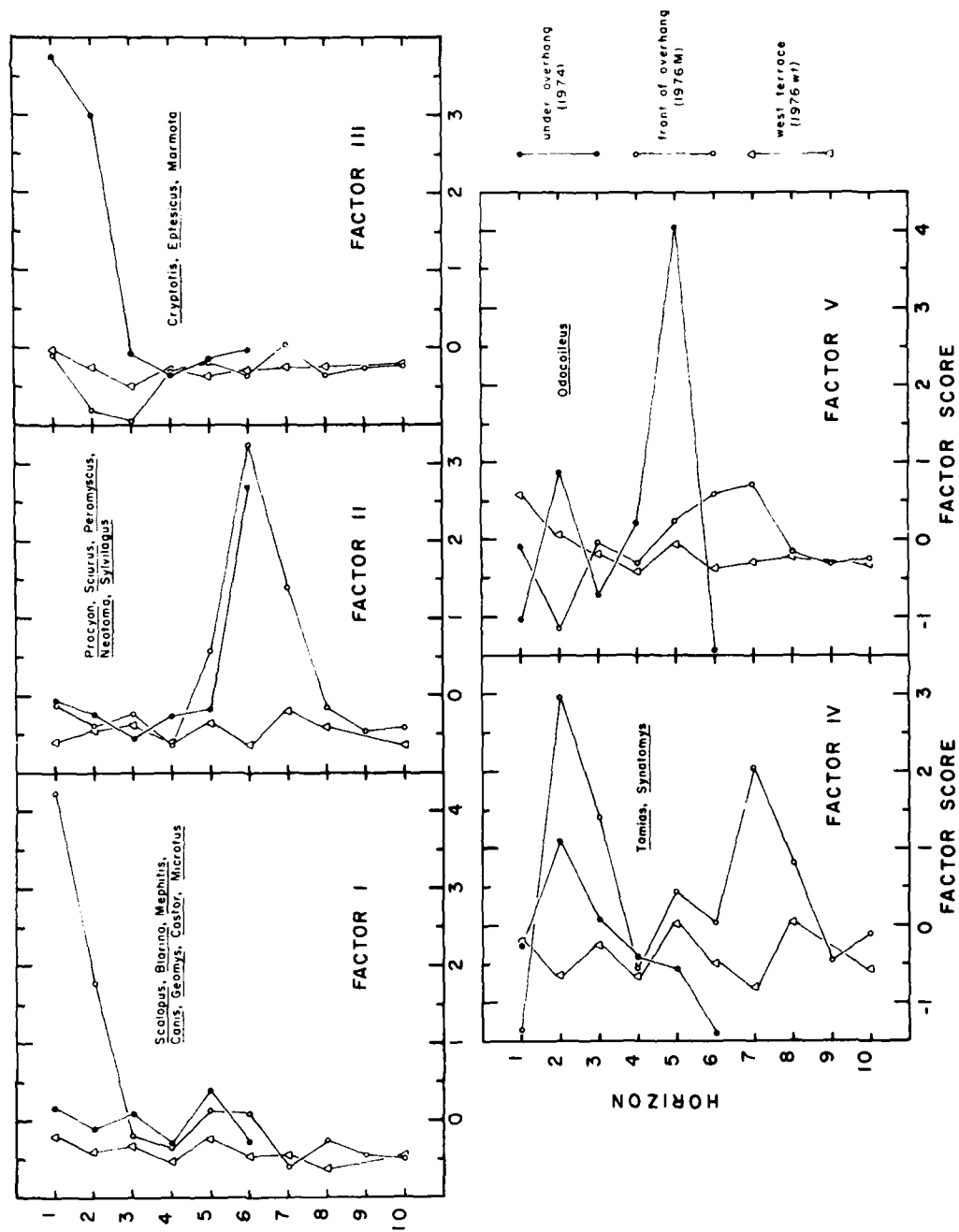


Figure 9.4. Factor scores for MNI-based factor analysis. Listed taxa had loadings of ≤ 0.6 for the indicated factors (Table 9.5).

TABLE 9.6

Correlations of Original Variables with Principal Factors

	Principal Factors				
	I	II	III	IV	V
<i>Meleagris gallopavo</i>	0.25	-0.13	0.55	0.58	-0.13
<i>Scalopus aquaticus</i>	0.85	0.36	-0.01	0.08	-0.07
<i>Cryptotis parva</i>	-0.07	0.30	0.78	0.35	0.16
<i>Blarina brevicauda</i>	0.95	0.03	0.05	-0.14	0.09
<i>Eptesicus fuscus</i>	-0.01	0.01	0.92	0.17	-0.10
<i>Procyon lotor</i>	0.09	0.77	0.16	0.11	-0.35
<i>Mephitis mephitis</i>	0.72	0.43	0.04	-0.19	-0.34
<i>Canis latrans/familiaris</i>	0.90	0.20	-0.01	0.14	0.28
<i>Marmota monax</i>	0.01	-0.04	0.95	0.14	0.00
<i>Tamias striatus</i>	0.18	0.12	0.22	0.83	-0.15
<i>Sciurus carolinensis/niger</i>	0.18	0.91	-0.01	0.07	0.04
<i>Geomys bursarius</i>	0.85	0.10	-0.03	0.36	0.13
<i>Castor canadensis</i>	0.93	0.10	0.03	0.11	-0.15
<i>Peromyscus</i> sp.	-0.09	0.63	0.31	0.58	0.13
<i>Neotoma floridana</i>	0.35	0.85	-0.02	0.16	0.16
<i>Synaptomys cooperi</i>	0.03	0.08	0.42	0.80	-0.04
<i>Microtus ochrogaster/</i> <i>Pitymys pinetorum</i>	0.68	0.31	-0.05	0.53	0.00
<i>Sylvilagus floridanus</i>	0.43	0.84	-0.04	-0.08	0.22
<i>Odocoileus virginianus</i>	0.06	0.07	-0.01	-0.12	0.79
Percent of variation	38.90	21.60	12.70	6.50	5.90
Cumulative percent of variation	38.90	60.50	73.20	79.70	85.60

85.6% of the total variation.

Factor I in the MNI analysis is very similar to Factor III in the E analysis. The main peak occurred in front of the overhang in Horizons 1 and 2. Loadings for the E analysis were high for three taxa, *Scalopus*, *Blarina*, and *Mephitis* (Table 9.4). The same taxa are also highly influential in the MNI test, in addition to other animals: coyote or dog (*Canis*), pocket gopher (*Geomys*), beaver (*Castor*), small microtines (*Microtus/Pitymys*; Table 9.6). Both natural and cultural agents are probably involved in the deposition pattern. The small, burrowing forms, i.e., *Scalopus*, *Blarina*, *Geomys*, *Mephitis*, and *Microtus/Pitymys*, have low burn rates (Table 9.7). The larger animals, *Mephitis*, *Canis*, and *Castor*, generally have higher burn rates, although small sample size is a problem (Table 9.3).

Factor II in the MNI analysis (Fig. 9.4) closely parallels Factor I in Figure 9.3, the E-based analysis. A major peak in Horizons 5, 6 and 7 in front of the overhang is attributable to subsistence based on medium-sized mammals (Table 9.6). With the exception of *Peromyscus*, all the highly-loaded species would have provided relatively high meat yields; not surprisingly, all had high rates of burned bone (Table 9.7).

TABLE 9.7

Percentages of Burned Bone for Taxa with High Loadings in the
MNI Factor Analysis.

Taxon	Horizons			
PERCENT BURNED IN HORIZONS 1 and 2 FOR TAXA LOADED HIGH ON FACTOR I.				
	1	2		
<i>Scalopus aquaticus</i>	1.9	0.0		
<i>Blarina brevicauda</i>	4.0	0.0		
<i>Mephitis mephitis</i>	33.3	100.0		
<i>Canis</i> sp.	0.0	40.0		
<i>Geomys bursarius</i>	5.9	6.3		
<i>Castor canadensis</i>	50.0	0.0		
<i>Microtus ochrogaster/Pitymys pinetorum</i>	4.1	3.3		
PERCENT BURNED IN HORIZONS 5, 6 and 7 FOR TAXA LOADED HIGH ON FACTOR II.				
	5	6	7	
<i>Procyon lotor</i>	31.3	6.5	10.0	
<i>Sciurus</i> sp.	16.3	15.0	20.4	
<i>Peromyscus</i> sp.	2.0	0.0	0.0	
<i>Neotoma floridana</i>	15.5	13.5	12.5	
<i>Sylvilagus floridanus</i>	19.3	21.3	21.3	
PERCENT BURNED IN HORIZONS 1 and 2 FOR TAXA LOADED HIGH ON FACTOR III.				
	1	2		
<i>Cryptotis parva</i>	0.0	0.0		
<i>Eptesicus fuscus</i>	8.3	0.0		
<i>Marmota monax</i>	20.0	83.3		
PERCENT BURNED IN HORIZONS 2, 3, 7 and 8 FOR TAXA LOADED HIGH ON FACTOR IV.				
	2	3	7	8
<i>Tamias striatus</i>	0.0	6.7	0.0	0.0
<i>Synaptomys cooperi</i>	0.0	0.0	0.0	0.0

Deposition of bone under the overhang in Horizons 1 and 2 was represented on Factor III of the MNI test (Fig. 9.4), as it similarly was on Factor II of the E analysis (Fig. 9.3). Natural mortality of least shrews (*Cryptotis parva*) and big brown bats (*Eptesicus fuscus*) was involved (Tables 9.6 and 9.7). The woodchuck (*Marmota monax*) was likely culturally deposited (Table 9.7).

Factor IV in both analyses was roughly parallel in that both had peaks near the bottom and top of the main excavation (Figs. 9.3 and 9.4). The excavation under the overhang yield fauna that also peaked in the upper levels. Only one species, the southern bog lemming (*Synaptomys cooperi*), was highly involved in both MNI and E analyses (Table 9.6).

The other taxon highly loaded on Factor IV in the MNI analysis was the eastern chipmunk (*Tamias striatus*). Deposition due to natural processes is indicated because of the virtual lack of burning on the bones (Table 9.7). The effect of Hypsithermal is suggested by the lack of these moist-environment (*Synaptomyza*) and forest (*Tamias*) inhabitants during Horizons 5 and 6.

Factor V of the MNI analysis is erratic and relates to only one species, *Odocoileus virginianus* (Table 9.6). The most meaningful interpretation is that deer utilization varied through time and across the site. As with Factor V of the E analysis, it will be hereafter ignored.

In summary, there are several persistent deposition patterns apparent in both factor analyses. One occurred in strata laid down during the Hypsithermal (Horizons 5, 6 and 7). It almost surely represents the subsistence practices of the human inhabitants. Fish and medium-sized mammals were the animals involved; deer had reduced scores.

A second pattern involved natural and cultural events under the overhang in the upper horizons after the Hypsithermal. Bats and shrews were probably present due to natural mortality. Deer, woodchuck, turkey, and centrarchids were most likely deposited by humans. Although one must be cautious due to an inadequate level of identification, it is interesting to speculate on the presence of centrarchids in post-Hypsithermal horizons and of catostomids and ictalurids in the levels deposited during the Hypsithermal. The majority of catostomids and ictalurids inhabit slow-moving water and many centrarchids prefer faster water. Because more pooling probably occurred in the Pomme de Terre River during the Hypsithermal due to decreased effective precipitation, the difference of fish distribution may have an environmental basis.

A third depositional pattern mainly involved natural deposition of fauna in front of the overhang in Horizons 1 and 2. Burrowing forms predominate this fauna. Perhaps the substrata was more suitable for these species than it had been previously.

The final pattern indicated similarity between upper and lower horizons. The middle horizons, which represent the Hypsithermal, tended to have negative values. The taxa responsible for this pattern are aquatic, moist, or deep forest forms.

Clinal Variation. As indicated in the introductory section, clinal morphological variation may be a sensitive environmental indicator. Two genera from the Rodgers fauna were present in sufficient numbers for analysis. The first, squirrels of the genus *Sciurus*, potentially has two species present in the site: *niger* and *carolinensis*. *Sylvilagus*, the second animal, almost certainly is represented by a single species, the eastern cottontail (*S. floridanus*), throughout the Holocene record. It is conceivable that the swamp rabbit (*Sylvilagus aquaticus*) could be present early in the record when the forest around Rodgers Shelter was probably more mesic (King 1978). Likewise, the desert cottontail (*S. auduboni*) could have extended its range eastward during the more xeric Hypsithermal. No data have been generated to indicate that either event happened and, thus, the possibility of a multiple species *Sylvilagus* complex is slight.

To successfully deal with *Sciurus* it is necessary to be able to reliably separate the two species, but that is impossible if only based

on qualitative characteristics of most skeletal elements. Therefore, we used quantitative measurements and multivariate techniques, i.e., discriminant function analysis, to separate the species. Once species separation is achieved, we hoped to (1) show a shift in the proportion of species as climate changed during the Hypsithermal, and (2) find morphological shifts related to climate change for each species. Habitat preference of the two species overlap, but generally the gray squirrel (*S. carolinensis*) occupies heavy bottomland and mesophytic forests while the fox squirrel (*S. niger*) inhabits open forests and forest edges. The present-day geographic range of the fox squirrel extends to the western portion of Oklahoma, Kansas and Nebraska, in contrast to the gray squirrel which is only found as far west as eastern Oklahoma, Kansas and Nebraska. Otherwise, the two squirrels are generally sympatric throughout the eastern United States, except in the northeast. To accommodate the variation present in this vast range a sample of 186 (93 *S. carolinensis* and 93 *S. niger*) present day squirrel skeletons were accumulated from localities shown in Figure 9.5. A few isolated specimens (19) were near, but not actually from the localities indicated in Figure 9.5. The intralocality distances for eastern *S. niger* and *S. carolinensis* were generally short while the western *S. niger* collections tended to be diffuse. Preliminary analyses of measurements indicated only slight sexual dimorphism, particularly for fox squirrels; nonetheless, differences due to sex and age were not considered further in the study.

A total of 114 measurements were taken on each skeleton (Table 9.8). The emphasis of the measurements was on the ends of bones; these are the parts that tend to be preserved in prehistoric sites and are suitable for identification. Measurements were taken to a tenth of a millimeter by vernier calipers or a micrometer disk in a 10X dissecting microscope. Optical error in micrometer measurements was corrected. The choice of skeletal elements to be used in analysis of prehistoric bones was based on two criteria: (1) the ability to reliably distinguish statistically between the two species (see later in section), and (2) occurrence in the prehistoric sites.

Measurements were first standardized by the z-score transformation:

$$z = \frac{x_i - \bar{x}}{s}$$

where x_i is the original value of the i^{th} case for the variable being transformed, \bar{x} is the mean of the variables, and s is the standard deviation (Nie *et al.* 1975). After transformation, data were entered into discriminant function analysis. This multivariate technique is designed to maximally distinguish between groups, in this instance species, by forming a linear combination of original, transformed measurements. In this study, only one discriminant function could be derived because only two groups are present. Data were evaluated in two ways: (1) through analysis where the inherent separability of the groups was determined, and (2) through classification where known and unknown individuals were reassigned to one or another of the groups. In the present application, the degree of separation for a particular skeletal element for species discrimination was evaluated through the use of canonical correlations

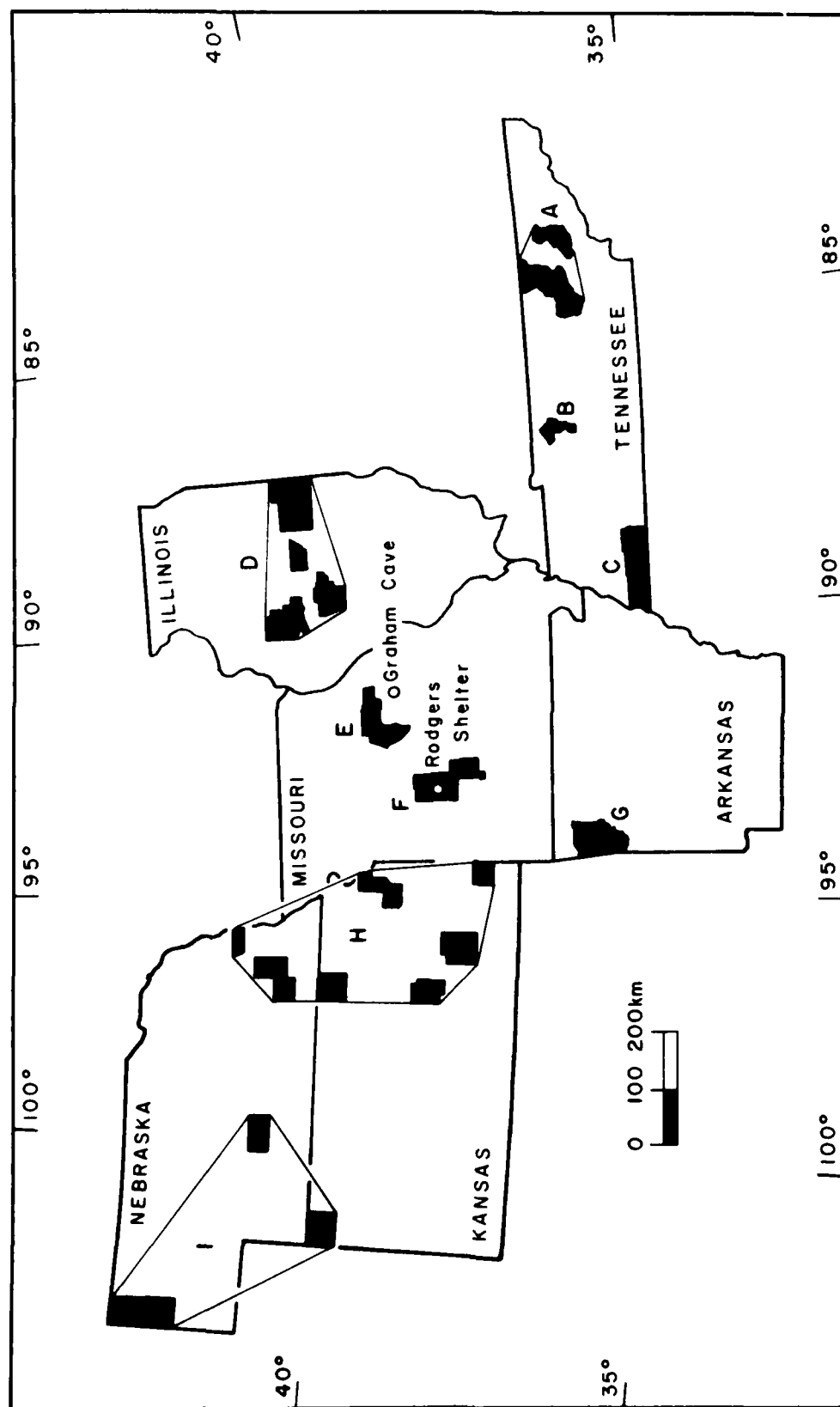


Figure 9.5. Map of collection localities for modern squirrels.

TABLE 9.8

List of Squirrel Measurements

Number	Element ¹	Description ²
1	Scapula	max wh of glenoid cavity
2	Scapula	max lh of glenoid cavity
3	Scapula	lh from tip of scapular body to supra-glenoid tubercle
4	Scapula	max wh across scapular body
5	Humerus	lh from ridge of medial epicondyle to top of head
6	Humerus (p)	head dh - medial view
7	Humerus (p)	head wh - posterior view
8	Humerus (p)	head ht from "lip" of neck to tip of head - medial view
9	Humerus (d)	max wh
10	Humerus (d)	dh at narrowest point of trochlea - ventral view
11	Humerus (d)	anterior wh of trochlea at radial fossa edge
12	Humerus (d)	posterior wh of trochlea at olecranon fossa edge
13	Radius	total lh
14	Radius (p)	wh of capitular fovea
15	Radius (p)	dh of capitular fovea
16	Radius (d)	wh of carpal articular surface
17	Radius (d)	dh of carpal articular surface
18	Ulna	total lh
19	Ulna (p)	max lh of trochlear notch
20	Ulna (p)	dh of body at midpoint of trochlear notch - lateral view
21	Ulna (p)	narrowest wh of trochlear notch - anterior view
22	Ulna (p)	distance from midpoint of trochlear notch to tip of olecranon - anterior view
23	Ulna (d)	max wh of styloid process - anterior view
24	Ulna (d)	max dh of styloid process - medial view
25	Pelvis	max lh from tip of ischium to tip of ilium
26	Pelvis	min wh of body of ilium - medial-dorsal view
27	Pelvis	min dh of body of ilium - lateral-dorsal view
28	Pelvis	min wh of body of ischium - lateral-ventral view
29	Pelvis	min dh of body of ischium - lateral-dorsal view
30	Pelvin	dorsal-to-ventral distance across "floor" of acetabular fossa
31	Pelvin	lh of acetabular notch - posterior view
32	Femur	total lh from greater trochanter to tip of medial condyle
33	Femur (p)	of head - medial view
34	Femur (p)	min wh of neck - medial view
35	Femur (p)	min dh of neck - anterior view
36	Femur (p)	min wh at narrowest point beneath neck - posterior view

¹ (p) = proximal; (d) = distal

² lh = length; wh = width; dh = depth; ht = height

TABLE 9.8 (continued)

Number	Element	Description
37	Femur (p)	lh of trochanteric fossa - medial-posterior view
38	Femur (p)	wh of trochanteric fossa - medial-posterior view
39	Femur (d)	distance across intercondyloid fossa - posterior view
40	Femur (d)	lh of intercondyloid fossa - posterior view
41	Femur (d)	max wh at condyles - posterior view
42	Femur (d)	max wh of trochlea
43	Tibia	total lh
44	Tibia (p)	max wh of intercondylar eminence - dorsal view
45	Tibia (p)	max wh at condyles - dorsal view
46	Tibia (p)	max wh of medial condyle - dorsal view
47	Tibia (p)	max wh of lateral condyle - dorsal view
48	Tibia (d)	max wh - anterior view
49	Tibia (d)	max dh - medial view
50	Astragalus	min wh of neck - dorsal view
51	Astragalus	min wh of body - dorsal view
52	Astragalus	min diagonal of body - dorsal view
53	Astragalus	max lh of head - anterior view
54	Astragalus	max wh of head - anterior view
55	Astragalus	lh of lateral face
56	Astragalus	wh of medial face
57	Astragalus	diagonal dh of calcaneal articular surface
58	Calcaneum	max dorsoventral ht - medial view
59	Calcaneum	total lh
60	Calcaneum	min wh of body - posterior view
61	Calcaneum	lh of lateral edge of posterior articular surface
62	Calcaneum	dh of calcaneal tuberosity
63	Calcaneum	wh of calcaneal tuberosity
64	Calcaneum	dh of cuboid facet
65	Calcaneum	wh of cuboid facet
66	Calcaneum	max wh - dorsal view
67	Skull	lh of tooth row (sockets)
68	Skull	palate wh between sockets of first molars
69	Skull	lh from midline ridge on occipital bone to top of nasals
70	Skull	min wh of frontals
71	Skull	max wh at zygomatic arches
72	Skull	max wh of foramen magnum
73	Skull	max dh of foramen magnum
74	Skull	distance between hypoglossal nerve foramina
75	Skull	incisor wh at base of wear area - anterior view
76	Skull	incisor dh at base of wear area - medial view
77	Skull	incisor curvature ³
78	Skull	wh of posterior foramen of petrous
79	Skull	lh of anterior lateral foramen of petrous
80	p ⁴	buccal lh - occlusal view

³Incisor curvature was the radius of exterior enamel curvature near the tip.

TABLE 9.8 (concluded).

Number	Element	Description
81	p ⁴	wh at midpoint - occlusal view
82	p ⁴	buccal ht - root "ceiling" to highest cusp point
83	M ¹	buccal lh - occlusal view
84	M ¹	wh at midpoint - occlusal view
85	M ¹	buccal ht - root "ceiling" to highest cusp point
86	M ²	buccal lh - occlusal view
87	M ²	wh at midpoint - occlusal view
88	M ²	buccal ht - root "ceiling" to highest cusp point
89	M ³	lingual lh - occlusal view
90	M ³	anterior wh - occlusal view
91	M ³	lingual ht - root base to highest cusp point
92	Mandible	lh of tooth row (sockets)
93	Mandible	wh of tooth row (sockets) - at posterior end of M ₂
94	Mandible	incisor dh at base of wear area - medial view
95	Mandible	incisor wh at base of wear area - ventral view
96	Mandible	incisor curvature ³
97	Mandible	max lh of wear area of incisor
98	Mandible	lh of mandibular notch
99	Mandible	distance between mental foramen and anterior edge of premolar socket
100	Mandible	dh at anterior edge of premolar socket - lateral view
101	Mandible	wh at anterior edge of premolar socket - dorsal view
102	Mandible	distance from tip of condylar process to point of bone between incisors
103	Mandible	distance from tip of condylar process to mandibular foramen
104	P ₄	lingual lh - occlusal view
105	P ₄	posterior wh - occlusal view
106	P ₄	buccal ht - root "ceiling" to highest cusp point
107	M ₁	lingual lh - occlusal view
108	M ₁	posterior wh - occlusal view
109	M ₁	max diagonal - occlusal view
110	M ₁	buccal ht - root "ceiling" to highest cusp point
111	M ₂	lingual lh - occlusal view
112	M ₂	posterior wh - occlusal view
113	M ₂	max diagonal - occlusal view
114	M ₂	buccal ht - root "ceiling" to highest cusp point
115	M ₃	max diagonal - occlusal view
116	M ₃	anterior wh - occlusal view
117	M ₃	lingual ht - root base to highest cusp point

(R) and Wilks' Lambda (λ). As the ability of the discriminant function to separate groups increases, R approaches 1.0 and λ approaches 0.0. Assignment of prehistoric species was achieved through use of the classi-

fication phase of discriminant function analysis. Discriminant scores, i.e., the values of the discriminant function for each case, were found useful to elucidate geographic patterns. Cases of both reference and prehistoric species with missing original variables were deleted from the data set.

Some skeletal elements proved to be better than others for separating species (Table 9.9). The astragalus proved to be very good ($\lambda = 0.96$, $R = 0.897$) while most other elements ranged between λ values of 0.350 and 0.450. Skull and mandible characters were not any better than post-cranial elements in separating species. However, many of our modern species were road-kills with many missing skull characters; also the rudimentary upper premolar present in most *S. carolinensis* was not used as a character in the analysis. Greater degree of separation was always achieved using complete long bones rather than using ends of bones. Unfortunately, prehistoric long bone specimens were usually fragmented, thus rendering analysis of bone ends more practical. The elements chosen for further analysis, distal humerus, proximal radius and astragalus, generally had low λ values (0.385, 0.424, and 0.196 respectively) and were relatively common in the site. Figure 9.6 shows these elements and their measurements.

TABLE 9.9

List of Standardized Discriminant Function Coefficients.
(Variable numbers and abbreviations are from Table 9.8.)

Element and Variable	Function
Distal humerus	
9 max wh	-0.615
10 dh at narrowest point of trochlea	-0.158
11 anterior wh of trochlea at radial fossa edge	-0.314
12 posterior wh at trochlea at olecranon fossa edge	0.071
Proximal radius	
14 wh of capitular fovea	0.340
15 dh of capitular fovea	0.686
Astragalus	
50 min wh of neck - dorsal view	0 ¹
51 min wh of body - dorsal view	0.406
52 min diagonal of body - dorsal view	0.513
53 max lh of head - anterior view	0.135
54 max wh of head - anterior view	0.512
55 lh of lateral head	0 ¹
56 wh of medial face	-0.191
57 diagonal dh of calcaneal articular surface	-0.392

¹Variable not included by step-wise procedure

The modern pattern of geographic variation for both species of squirrel indicated east-west clines (Fig. 9.7). Because the two species could not be absolutely separated (Table 9.10) actual and

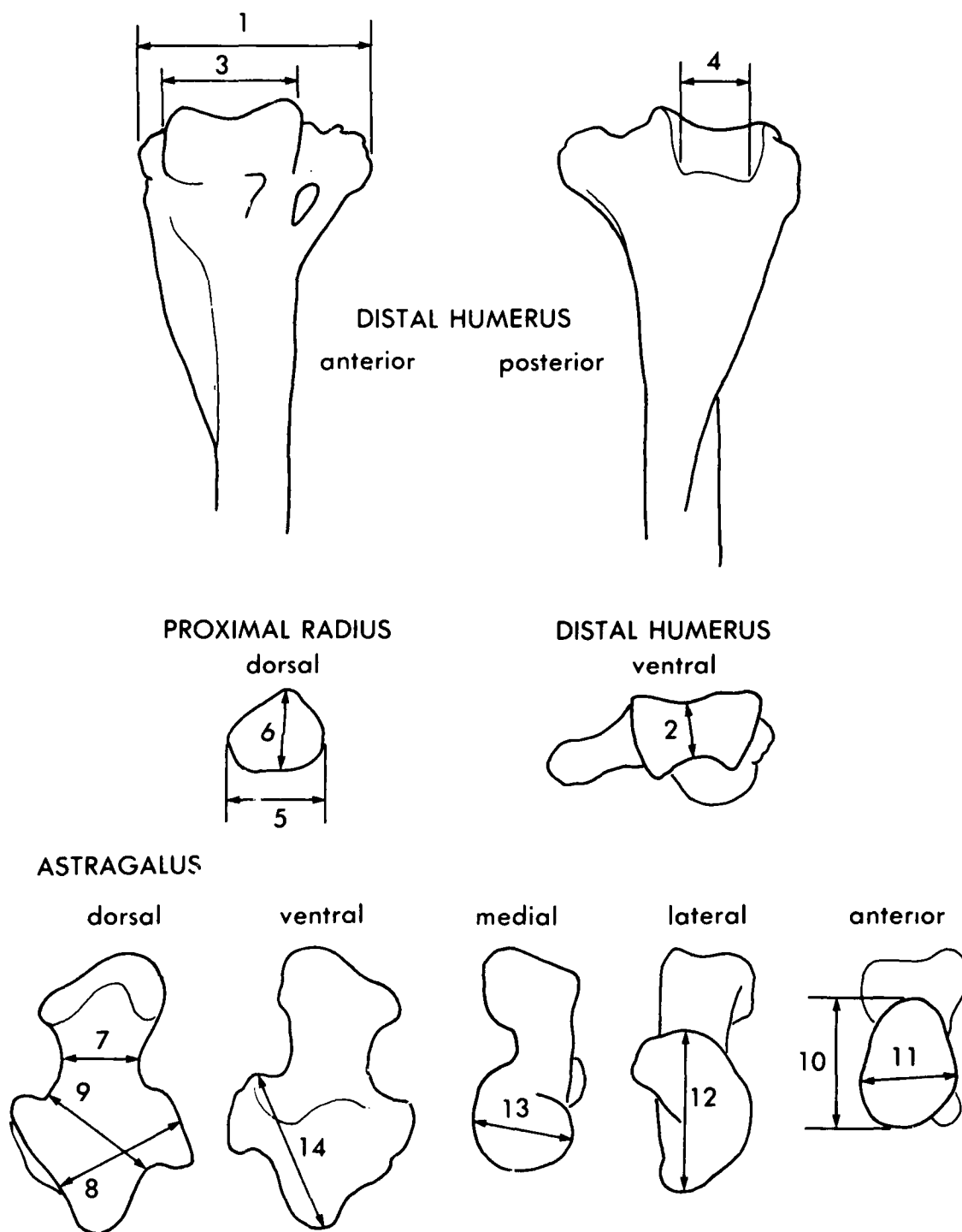


Figure 9.6. Measurements taken on selected post-cranial elements of *Sciurus*. Numbers on figure refer to the following numbers in the character description in Table 9.8: 1=9, 2=10, 3=11, 4=12, 5=15, 6=14, 7=50, 8=51, 9=52, 10=53, 11=54, 12=55, 13=56, and 14=57.

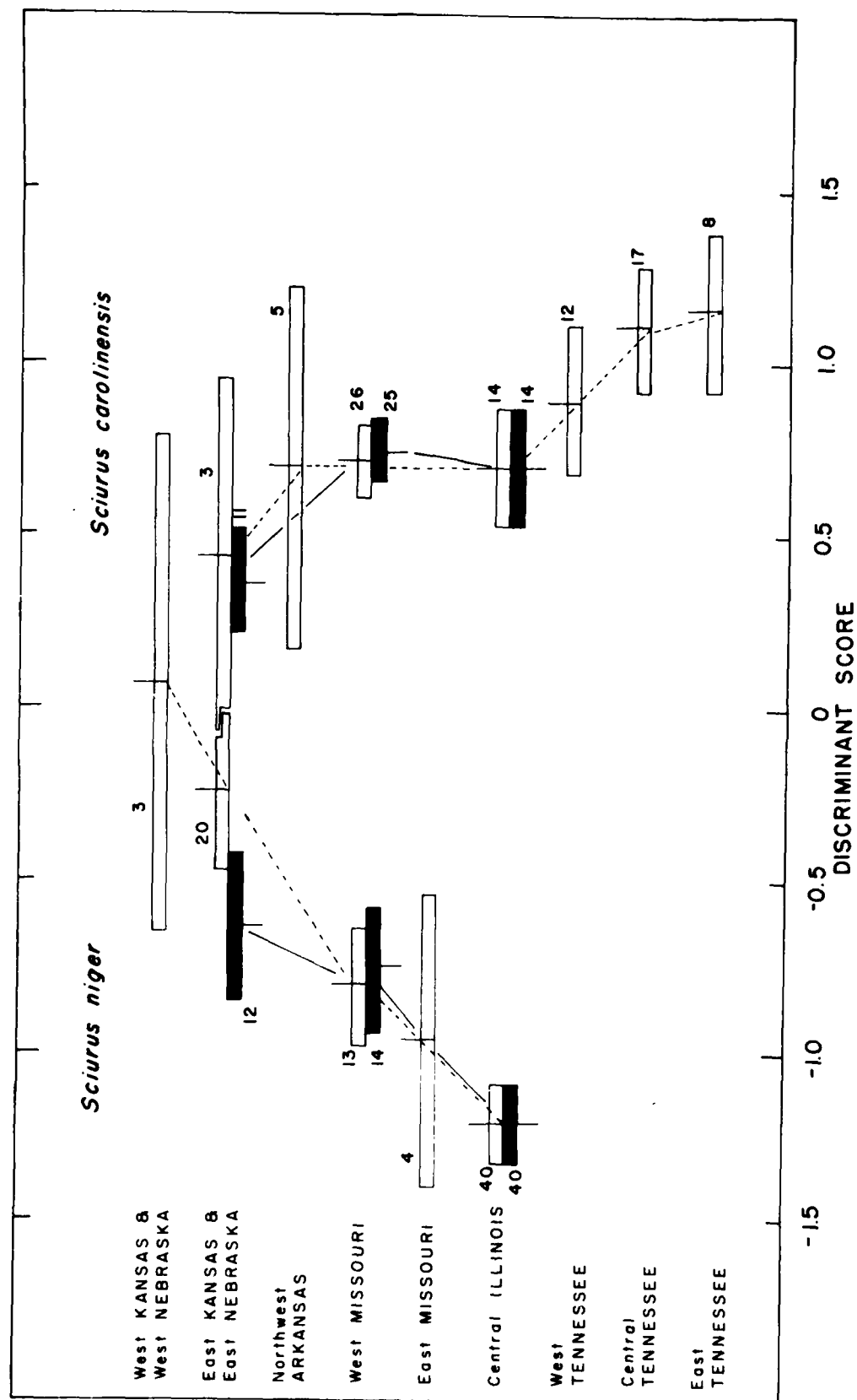


Figure 9.7A. Discriminant scores of modern squirrels based on distal humerus.

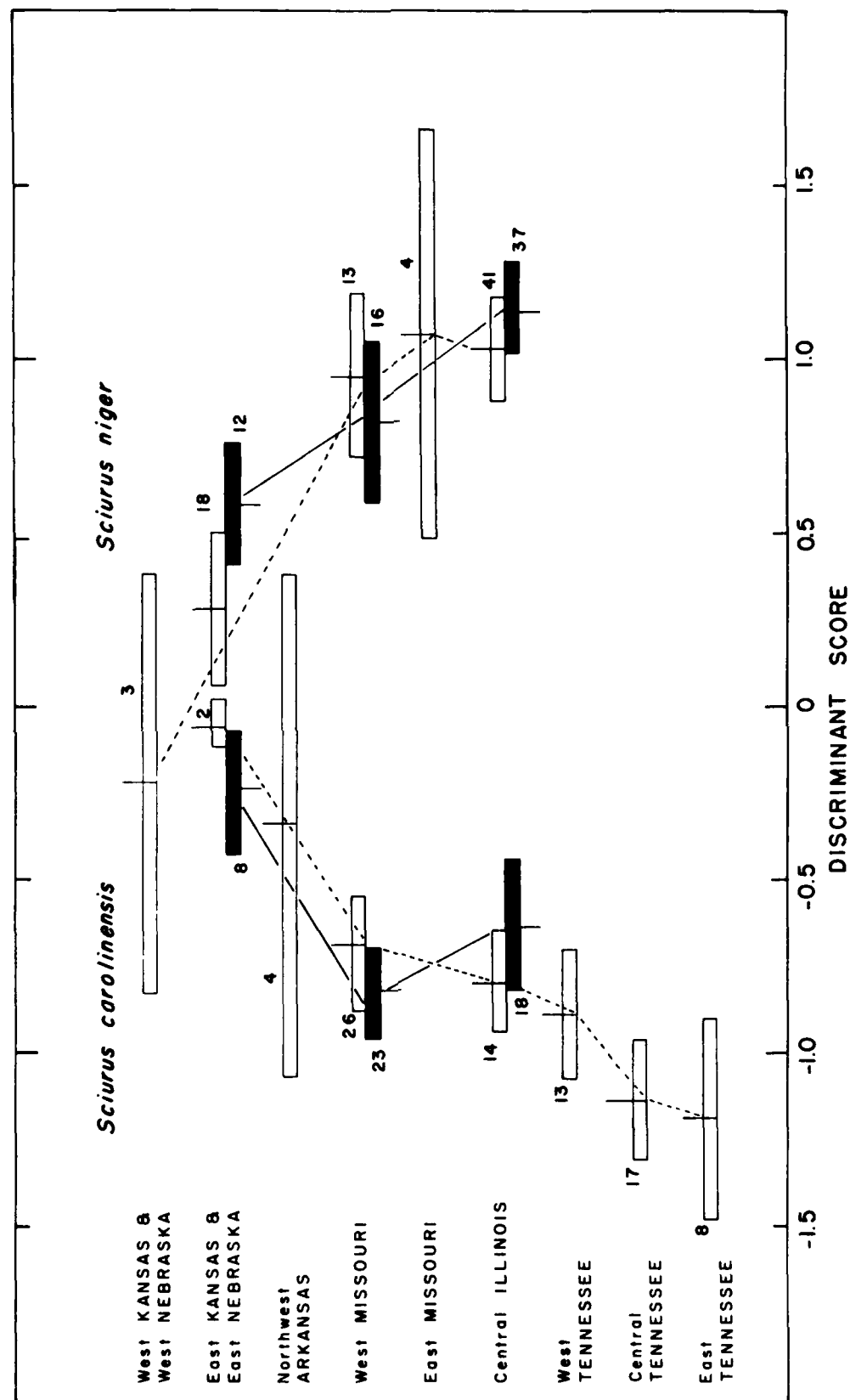


Figure 9.7B. Discriminant scores of modern squirrels based on the proximal radius.

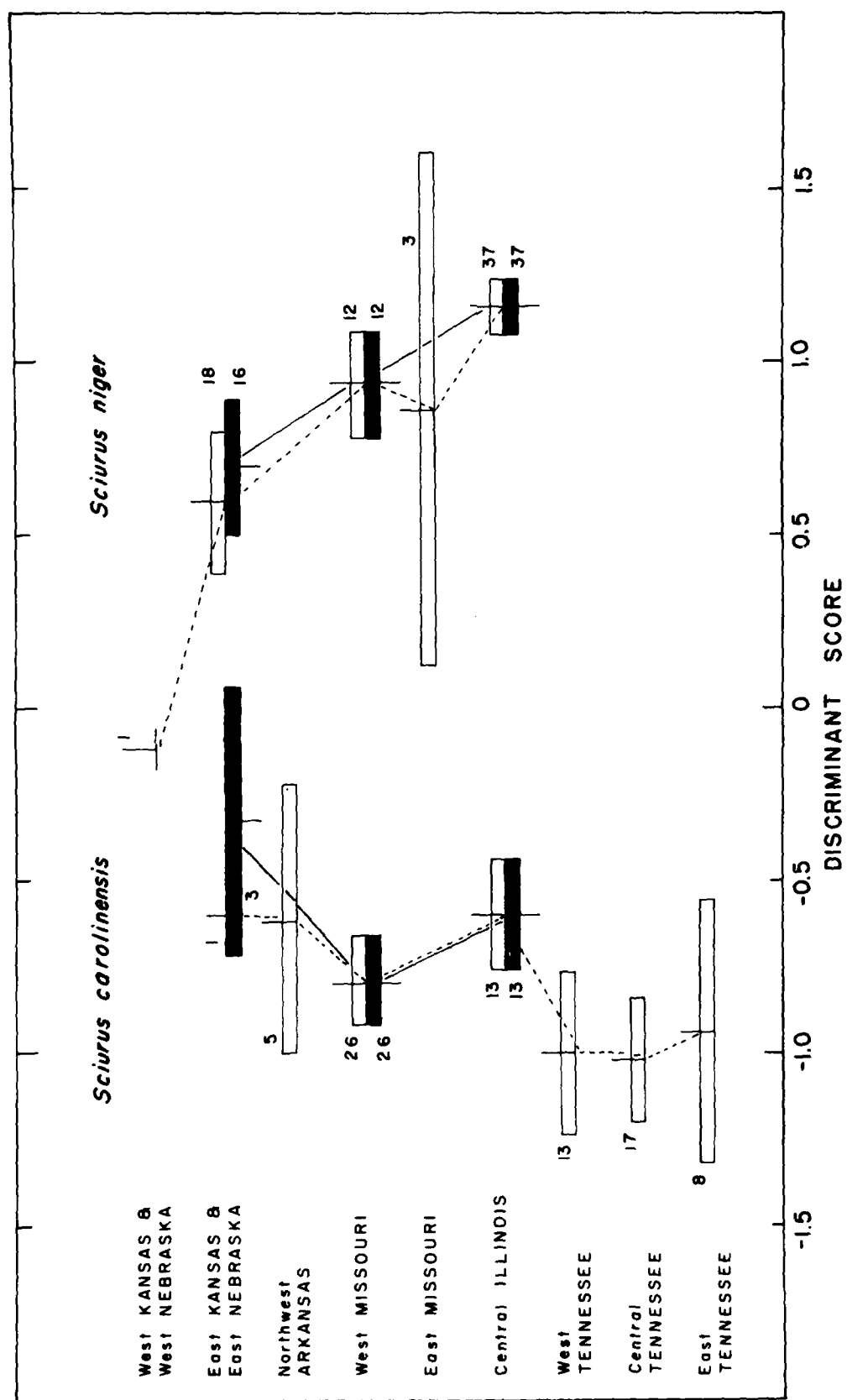


Figure 9.7C. Discriminant scores of modern squirrels based on the astragalus.

TABLE 9.10

Comparison of degree of separation between *Sciurus* species for different skeletal elements. Character numbers refer to those defined in Table 9.8. See text for explanation of R and λ .

Element	Characters	N	λ	R
Scapula	1 - 4	94	.462	.734
prox. scapula	1 - 2	118	.484	.719
Humerus	5 -12	118	.313	.829
prox. humerus	6 -18	121	.356	.802
dist. humerus	9 -12	120	.385	.784
Radius	13 -17	110	.407	.770
prox. radius	14 -15	114	.424	.759
dist. radius	16 -17	112	.491	.713
Ulna	18 -24	98	.310	.831
prox. ulna	19 -22	112	.532	.684
dist. ulna	23 -24	100	.614	.621
Pelvis	25 -31	97	.376	.790
Ilium	26 -27	118	.520	.693
Ischium	28 -29	117	.539	.629
Acetabulum	30 -31	114	.704	.544
Femur	32 -42	114	.295	.840
prox. femur	33 -38	119	.402	.773
dist. femur	39 -42	119	.440	.748
Tibia	43 -49	111	.325	.821
prox. tibia	44 -47	117	.432	.754
dist. femur	48 -49	117	.350	.806
Astragalus	50 -57	163	.196	.897
Calcaneum	58 -66	159	.390	.781
Subset	58, 60, 63, 64, 66	160	.403	.773
Skull	67 -77	---	---	---
Subset	67, 68, 72, 73	73	.997	.059
Upper incisor	75 -77	56	.456	.738
Upper cheek teeth P ⁴	80 -82	51	.374	.751
M ¹	83 -85	51	.331	.818
M ²	86 -88	50	.356	.802
M ³	89 -91	50	.550	.671
Mandible	92-103	61	.210	.889
Lower incisor	94 -96	110	.663	.580
Lower cheek teeth P ₄	104-106	48	.545	.675
M ₁	107-110	49	.331	.818
M ₂	111-114	47	.513	.698
M ₃	115-117	30	.665	.579

apparent clines are shown. An actual cline is based upon discriminant scores of individuals from particular localities regardless of computer-generated classification; thus, the real world pattern of variation is shown. Apparent clines are those which are based on computer-generated

classification. It is necessary to consider apparent clines because specific identification of prehistoric specimens is not known *a priori* and some misclassifications are included. Actual and apparent clines for both species parallel each other when elements of the two species can be reliably separated, e.g., those with low λ values in Table 9.10. Notice that within a species actual and apparent diverge greatest in the west where there is the most overlap between species.

The clines for the two squirrel species are in opposite directions with congruence in the west. *Sciurus carolinensis* increases in size toward the west; the sample size for eastern Kansas is small, but Jones and Cortner (1960) have reassigned specimens from this locality into *S. carolinensis pennsylvanicus*, a larger, northern race. In contrast, *S. niger* decreases in size to the west. Examination of the loadings of the original variables on the discriminant function reveals that the difference between species is predominantly based on size (Table 9.9). With the exception of the astragalus, where a couple of variables had negative values, the loadings were in the same direction for a particular element.

Biologically it is not immediately apparent why the clines for the two species are convergent toward the west (this study) and the north (this study; McNab 1971). The two species are ecologically and physiologically similar, yet no character displacement is evident. Obviously more study of modern squirrels is necessary to resolve the issue.

The prehistoric squirrel elements were entered into discriminant function analysis as unknowns and, subsequently, classified to species on the basis of discriminant scores. Discounting those specimens with missing data, most of the material classified into *S. carolinensis* (Table 9.11). In order to summarize information from all three elements, means of original variables were generated for all modern localities and prehistoric horizons. Squirrels from Graham Cave, another archaeological site 190 km east-northeast of Rodgers Shelter were included as separate entries (they also had been classified *carolinensis* by discriminant function analysis; Table 9.11); additional information about Graham Cave can be found in Klippel (1971). Modern gray squirrels that were computer classified as fox squirrels were deleted from further analysis, while fox squirrels classified as grays were included. This strategy was used to make the modern sample comparable to the computer-classified prehistoric specimens. The means and other descriptive statistics are listed in Table 9.12.

These data were subjected to factor analysis with fourteen variables (means of character measurements) and eleven cases (7 modern localities, 2 Rodgers Shelter horizons and 2 Graham Cave zones). Four unrotated factors were extracted accounting for 93.0% of the total variation. Factor I and Factor II are shown in Figure 9.8. For the modern sample the trend for Factor I is increasing size from east to west. The obvious exception is the sample from northwestern Arkansas. Unfortunately, if any biological meaning is evident by the position of this locality, it is obscured by small sample size (Table 9.12). Factor I mainly results from measurements of the astragalus (Table 9.13). Factor II, which is greatly influenced by the distal humerus and proximal radius, also becomes larger from east to west in the modern sample (Table 9.13).

The influence of the Hypsithermal is apparent in the prehistoric squirrels. In both Rodgers Shelter and Graham Cave the squirrels become

TABLE 9.11

Classification of Prehistoric Squirrels (*Sciurus*)
from Rodgers Shelter and Graham Cave

Location	Element	Stratigraphic unit	No.	
			<i>S. carolinensis</i>	<i>S. niger</i>
Rodgers	Distal humerus	Horizon 5	10	0
		6	3	1
		7	5	0
		8	4	0
		9	1	0
	Proximal radius	3	1	0
		5	17	0
		6	6	0
		7	19	4
		8	4	1
	Astragalus	9	1	0
		2	0	1
		4	2	0
		5	3	3
		6	2	0
		8	0	1
		11	1	0
Graham	Distal humerus	Zone III	2	0
		IV	4	1
	Proximal radius	III	4	0
		IV	19	0
	Astragalus	III	1	0
		IV	8	0

larger on Factor I as the Hypsithermal develops. Factor II for Graham Cave parallels the comparable factor for the modern sample. Factor II is in the opposite direction from Rodgers Shelter squirrels. I cannot explain this apparent aberration, except to say that many of the sample sizes from the prehistoric sites are marginal (Table 9.12). Overall, the implication is that gray squirrel size increased during the Hypsithermal and that the size change paralleled modern east to west clinal variation.

There were sufficient remains in Rodgers Shelter to conduct a similar analysis on *Sylvilagus floridanus*. Fortunately it is unlikely that any other *Sylvilagus* species was present in the site, so that the analysis is more simple than it was for *Sciurus*. Control of modern geographic variation in *Sylvilagus*, however, is not as good, due to an insufficient number of modern specimens. Slight sexual dimorphism was found in modern cottontails (females are slightly larger), and age-specific size differences no doubt also exist. Nonetheless, differences due to sex and age are not further considered, in part because of lack of such controls on the prehistoric sample.

TABLE 9.12

Descriptive Statistics for Computer-Classified Gray Squirrel
(*Sciurus carolinensis*) Measurements

Locality/Horizon	Element	Variable No. ¹	\bar{x}^2	s	n
East Tennessee	Astragalus	50	2.61	0.18	8
		51	4.76	0.25	8
		52	4.08	0.20	8
		53	4.14	0.21	8
		54	3.15	0.22	8
		55	5.29	0.26	8
		56	3.48	0.18	8
		57	5.59	0.31	8
	Humerus (d)	9	10.63	0.34	8
		10	2.73	0.12	8
		11	5.84	0.24	8
		12	3.29	0.19	8
	Radius (p)	14	4.51	0.21	8
		15	3.55	0.13	8
Central Tennessee	Astragalus	50	2.59	0.11	17
		51	4.76	0.18	17
		52	4.09	0.16	17
		53	4.16	0.15	17
		54	3.15	0.14	17
		55	5.32	0.18	17
		56	3.51	0.16	17
		57	5.68	0.22	17
	Humerus (d)	9	10.66	0.52	17
		10	2.72	0.09	17
		11	5.82	0.19	17
		12	3.16	0.21	17
	Radius (p)	14	4.54	0.15	17
		15	3.56	0.14	17
West Tennessee	Astragalus	50	2.58	0.12	13
		51	4.69	0.21	13
		52	4.10	0.19	13
		53	4.17	0.18	13
		54	3.10	0.16	13
		55	5.28	0.24	13
		56	3.47	0.10	13
		57	5.54	0.27	13
	Humerus (d)	9	10.75	0.27	12
		10	2.77	0.13	12
		11	5.89	0.23	12
		12	3.22	0.21	12
	Radius (p)	14	4.65	0.20	13
		15	3.63	0.12	13

¹See Table 9.7.²Measurements in mm.

TABLE 9.12 (continued)

Locality/Horizon	Element	Variable No.	\bar{x}	s	n
Central Illinois	Astragalus	50	2.68	0.09	13
		51	4.75	0.14	13
		52	4.33	0.15	13
		53	4.23	0.18	13
		54	3.21	0.17	13
		55	5.47	0.18	13
		56	3.51	0.14	13
	Humerus (d)	57	5.73	0.28	13
		9	10.91	0.28	14
		10	2.90	0.14	14
		11	5.96	0.27	14
		12	3.17	0.18	14
	Radius (p)	14	4.73	0.20	18
		15	3.73	0.15	18
West Missouri	Astragalus	50	2.67	0.12	26
		51	4.80	0.18	26
		52	4.14	0.19	26
		53	4.32	0.15	26
		54	3.23	0.14	26
		55	5.42	0.20	26
		56	3.55	0.14	26
	Humerus (d)	57	5.74	0.21	26
		9	10.96	0.31	25
		10	2.81	0.13	25
		11	6.08	0.15	25
		12	3.40	0.27	25
	Radius (p)	14	4.74	0.17	26
		15	3.69	0.17	26
Northwest Arkansas	Astragalus	50	2.60	0.16	4
		51	4.80	0.22	4
		52	4.30	0.16	4
		53	4.35	0.17	4
		54	3.08	0.15	4
		55	5.25	0.29	4
		56	3.63	0.15	4
	Humerus (d)	57	5.65	0.37	4
		9	11.02	0.58	5
		10	2.86	0.11	5
		11	6.06	0.30	5
		12	3.48	0.24	5
	Radius (p)	14	4.50	0.10	3
		15	3.75	0.21	2
East Kansas	Astragalus	50	2.70	0.00	3
		51	4.77	0.06	3
		52	4.30	0.00	3
		53	4.35	0.10	4
		54	3.25	0.10	4
		55	5.43	0.06	3

TABLE 9.12 (continued)

Locality/Horizon	Element	Variable No.	\bar{x}	s	n
Rodgers/Hor. 5	Humerus (d)	56	3.37	0.12	3
		57	5.63	0.15	3
		9	11.30	0.31	11
		10	2.92	0.20	11
		11	6.20	0.14	11
	Radius (p)	12	3.41	0.26	11
		14	5.00	0.18	9
		15	3.81	0.12	8
	Astragalus	50	2.70	0.26	5
		51	4.94	0.19	5
		52	4.26	0.18	5
		53	4.26	0.27	5
		54	3.22	0.15	5
		55	5.38	0.33	4
		56	3.44	0.17	5
		57	5.60	0.37	5
Rodgers/Hor. 6/7	Humerus (d)	9	11.16	0.32	10
		10	2.85	0.14	10
		11	6.09	0.17	10
		12	3.23	0.20	10
		14	4.73	0.13	17
	Radius (p)	15	3.68	0.13	17
		50	2.57	0.06	3
		51	4.70	0.20	3
	Astragalus	52	4.20	0.17	3
		53	4.15	0.07	2
		54	3.10	0.10	3
		55	5.30	0.17	3
		56	3.33	0.06	3
		57	5.53	0.15	3
	Humerus (d)	9	11.14	0.39	8
		10	2.85	0.19	8
		11	6.11	0.17	8
		12	3.39	0.25	8
		14	4.74	0.18	25
Graham/Zone III	Radius (p)	15	3.71	0.13	25
		50	2.80	--	1
		51	4.60	--	1
	Astragalus	52	4.20	--	1
		53	4.40	--	1
		54	3.20	--	1
		55	5.50	--	1
		56	3.60	--	1
		57	5.60	--	1
	Humerus (d)	9	10.90	0.99	2
		10	2.55	0.35	2
		11	5.95	0.49	2
		12	3.15	0.49	2

TABLE 9.12 (concluded)

Locality/Horizon	Element	Variable No.	\bar{x}	s	n
Graham/Zone IV	Radius (p)	14	4.38	0.50	4
		15	3.68	0.22	4
	Astragalus	50	2.49	0.16	8
		51	4.36	0.17	8
		52	3.96	0.18	8
		53	4.06	0.15	8
		54	2.96	0.17	8
		55	4.99	0.27	8
		56	3.21	0.19	8
		57	5.28	0.37	8
	Humerus (d)	9	10.65	0.58	4
		10	2.70	0.27	4
		11	5.98	0.29	4
		12	3.08	0.32	4
	Radius (p)	14	4.49	0.26	20
		15	3.55	0.17	20

TABLE 9.13

Loadings of Original Variables on First Four Factors in Analysis
of Clinal Variation in *Sciurus carolinensis*

Element	Variable No. ¹	I	II	III	IV
Astragalus	50	0.95	0.23	0.06	-0.16
	51	0.39	0.16	0.72	0.40
	52	0.50	0.62	0.37	0.19
	53	0.65	0.59	0.28	-0.32
	54	0.88	0.14	0.28	0.31
	55	0.92	0.15	0.30	0.10
	56	0.47	-0.02	0.74	-0.46
	57	0.61	0.06	0.74	0.16
Humerus (d)	9	0.32	0.86	0.03	0.34
	10	-0.12	0.50	0.35	0.74
	11	0.07	0.91	-0.13	0.30
	12	-0.14	0.69	0.58	0.14
Radius (p)	14	0.20	0.45	-0.01	0.84
	15	0.37	0.86	0.18	0.18
Percent explained variation (unrotated factors)		54.0	22.1	9.4	7.5
Cumulative percent explained variation		54.0	76.1	85.5	93.0

¹See Table 9.8.

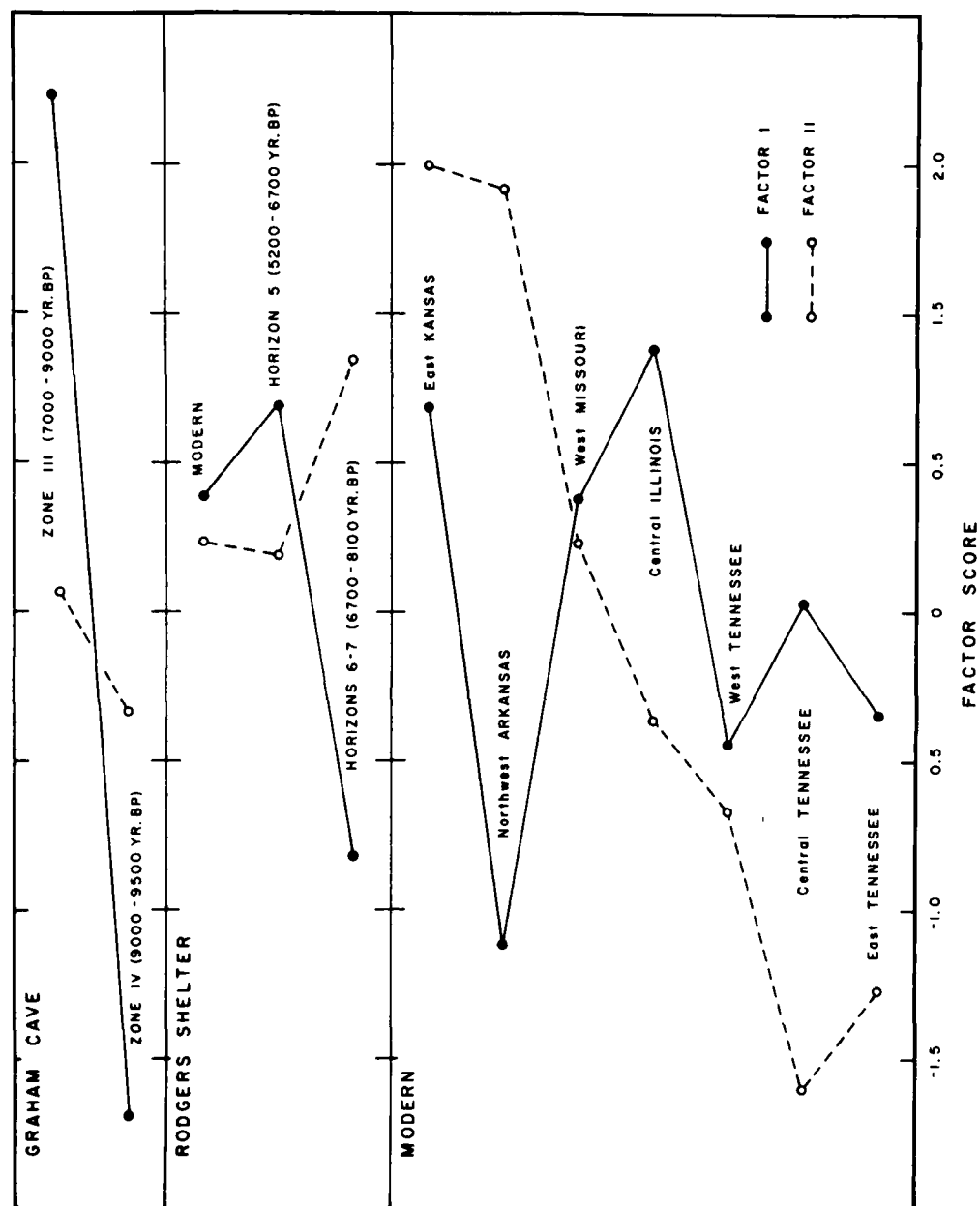


Figure 9.8. Clinal variation in modern and prehistoric gray squirrels (*Sciurus carolinensis*). Prehistoric specimens are from Rodgers Shelter and Graham Cave. Data points are factor scores for Factors I and II (see text and Table 9.13).

Three skeletal elements were selected for study: lower premolar, distal humerus, and astragalus. These were utilized because they (1) sampled different portions of the body and (2) were present in high numbers in the prehistoric bone. Three measurements were taken on the distal humerus, two on the premolar, and four on the astragalus (Fig. 9.9). Descriptive statistics were generated (Table 9.14), and character means were entered into factor analysis (six cases representing two modern localities and four Rodgers horizons; nine variables). Only one factor was extracted with an eigenvalue greater than 1.0, accounting for 90.7% of the total variation. All nine variables were highly loaded onto the factor (Table 9.15). A display of factor scores is shown in Figure 9.10. The modern localities indicate decreasing body size from east to west (central Illinois to western Missouri). The prehistoric rabbits similarly decreased in size during the Hypsithermal. In the post-Hypsithermal size increased to the modern level. As with gray squirrels, prehistoric clinal variation of *Sylvilagus* parallels modern geographic variation.

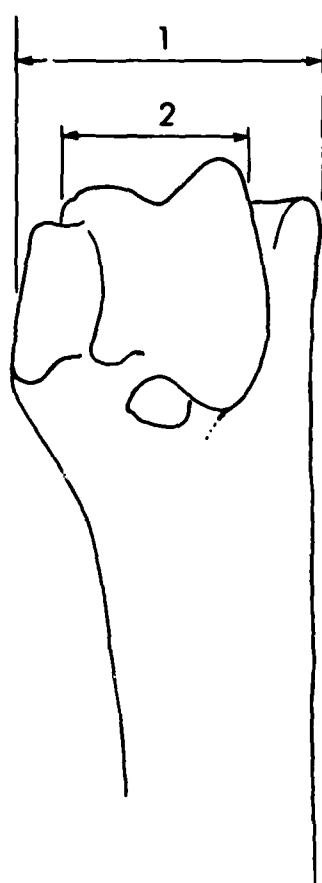
DISCUSSION

McMillan (1976) postulated that significant environmental change occurred around Rodgers Shelter during the Hypsithermal. The warmer/drier climate during that period produced more open habitat and concurrent increase in prairie forms. Before and after the Hypsithermal closed vegetation predominated. McMillan then related cultural events to these proposed environmental changes.

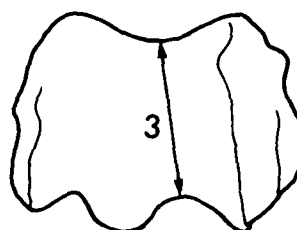
Data derived from the 1974 and 1976 excavations generally support McMillan's thesis, but differ in some detail. McMillan noted that when prairie species occurred, they appeared during the mid-Holocene. A similar pattern is also apparent from the 1974/1976 material (Table 9.16). For example, badger (*Taxidea taxus*) and bison (*Bison bison*) were found in Horizon 7, Franklin's ground squirrel (*Spermophilus franklini*) was in Horizons 5, 6 and 7, and spotted skunk (*Spilogale putorius*) was in Horizons 3, 5, 6 and 7. On the other hand, some open habitat forms were found when forests supposedly predominated, e.g., the thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*) in Horizon 10, Franklin's ground squirrel (*Spermophilus franklini*) in Horizon 1, and the woodchuck (*Marmota monax*) in Horizons 1 and 2. Confusing the picture further was the presence of forest-inhabiting species during the Hypsithermal (the chipmunk, *Tamias striatus*, in Horizons 5, 6, 7 and 8; the flying squirrel, *Glaucomys volans*, in Horizon 6). The conclusion is that both open and closed habitats were present in the vicinity of Rodgers Shelter for most, if not all, of the Holocene.

While the above presence and absence data are ambiguous in terms of climatic change, analysis of changes in morphology are less so. Size variation in *Sciurus* and *Sylvilagus* parallels east-west clinal variation present in modern conspecifics. F. B. King (Chapter 2), J. E. King (1978) and others have postulated a more mesic-than-present forest for this region in the early Holocene. This view is enhanced by the size of gray squirrels and eastern cottontails in the earlier levels at Rodgers Shelter and gray squirrels at Graham Cave. In all three cases early body size resembled modern forms found today farther east in more mesic regions.

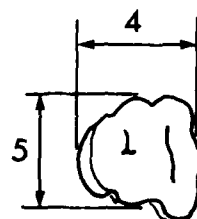
As climate became warmer/drier during the Hypsithermal, size of the



DISTAL HUMERUS
anterior



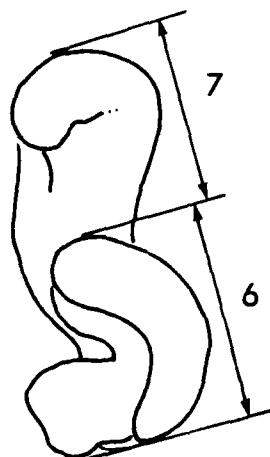
DISTAL HUMERUS
ventral



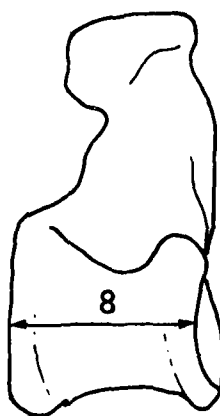
P³ — occlusal

ASTRAGALUS

lateral



dorsal



medial

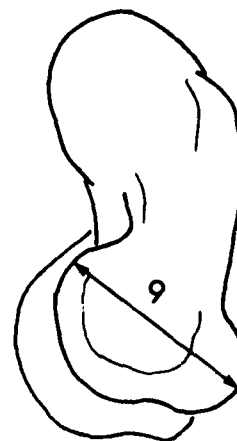


Figure 9.9. Measurements taken on *Sylvilagus* elements.

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HARRY S TRUMAN DAM AND RESERVOIR MISSOURI HOLOCENE
ADAPTATIONS WITHIN THE (U) ILLINOIS STATE MUSEUM
SOCIETY SPRINGFIELD M KAY JUN 82 DACW41-76-C-0011

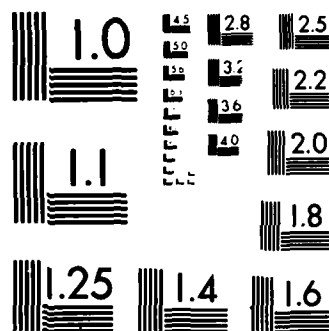
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLE 9.14

Descriptive Statistics for Measurements of *Sylvilagus floridanus*

Locality/Horizon	Element	Variable No.	\bar{x}	s	n
West Missouri	Humerus (d)	1	7.22	0.28	27
		2	3.64	0.19	27
		3	3.89	0.19	27
	Premolar	4	2.64	0.22	26
		5	2.32	0.19	26
	Astragalus	6	5.56	0.63	35
		7	4.97	0.43	35
		8	4.40	0.29	35
		9	4.80	0.50	35
Central Illinois	Humerus (d)	1	7.70	0.25	7
		2	3.88	0.19	7
		3	4.18	0.23	7
	Premolar	4	2.91	0.13	6
		5	2.46	0.10	6
	Astragalus	6	6.29	0.52	8
		7	5.27	0.57	8
		8	4.74	0.24	8
		9	5.41	0.34	8
Rodgers/Horizons 1-3	Humerus (d)	1	7.21	0.27	6
		2	3.71	0.35	6
		3	3.76	0.18	6
	Premolar	4	2.60	0.17	14
		5	2.34	0.14	14
	Astragalus	6	5.53	0.26	5
		7	5.04	0.36	6
		8	4.14	0.39	10
		9	4.49	0.51	9
Rodgers/Horizon 5	Humerus (d)	1	7.01	0.35	65
		2	3.65	0.20	73
		3	3.82	0.21	71
	Premolar	4	2.68	0.15	107
		5	2.33	0.17	106
	Astragalus	6	5.44	0.28	45
		7	4.93	0.47	39
		8	4.22	0.30	60
		9	4.58	0.47	48
Rodgers/Horizon 6	Humerus (d)	1	7.06	0.30	52
		2	3.72	0.26	55
		3	3.83	0.21	55
	Premolar	4	2.68	0.12	56
		5	2.33	0.14	56
	Astragalus	6	5.59	0.36	23
		7	4.93	0.35	16
		8	4.17	0.29	27
		9	4.71	0.30	23

TABLE 9.14 (concluded)

Locality/Horizon	Element	Variable No.	\bar{x}	s	n
Rodgers/Horizons 7-8	Humerus (d)	1	7.17	0.25	28
		2	3.77	0.22	34
		3	3.86	0.21	34
	Premolar	4	2.72	0.14	66
		5	2.36	0.15	65
	Astragalus	6	5.78	0.32	15
		7	5.01	0.48	10
		8	4.23	0.34	23
		9	4.82	0.42	17

TABLE 9.15

Loadings of Original Variables on Factor Analysis of Clinal Variation in *Sylvilagus floridanus*. Only one factor had eigenvalues greater than 1.0; rotation was, therefore, unnecessary.

Element	Variable No.	Loading on Factor I
Humerus (d)	1	0.95
	2	0.90
	3	0.97
Premolar	4	0.95
	5	0.97
Astragalus	6	0.99
	7	0.95
	8	0.92
	9	0.97
Percent explained variation		90.7

study species changed such that it resembled animals living toward the west today. During the post-Hypsithermal morphologies shifted again in favor of mesic conditions, but not to the extent that was apparent during the pre-Hypsithermal.

It appears, then, that there was environmental change during the last 9,000 to 10,000 years. The changes, however, were not drastic enough to precipitate a complete shift in species composition. Rather, all the habitats, i.e., upland forest, riparian forest, upland prairie, etc., were present in a mosaic pattern. As climate changed habitat patches expanded or contracted. For instance, as the Hypsithermal developed open habitats enlarged resulting in increased numbers of prairie animals already present, and perhaps, invasion by others requiring large habitat patches presently found farther west. Forest habitats were obviously still present, as indicated by the number of closed-habitat species found in the faunal record. Following the Hypsithermal conditions ameliorated in favor of closed vegetation and concomitant decrease in size of prairie habitat

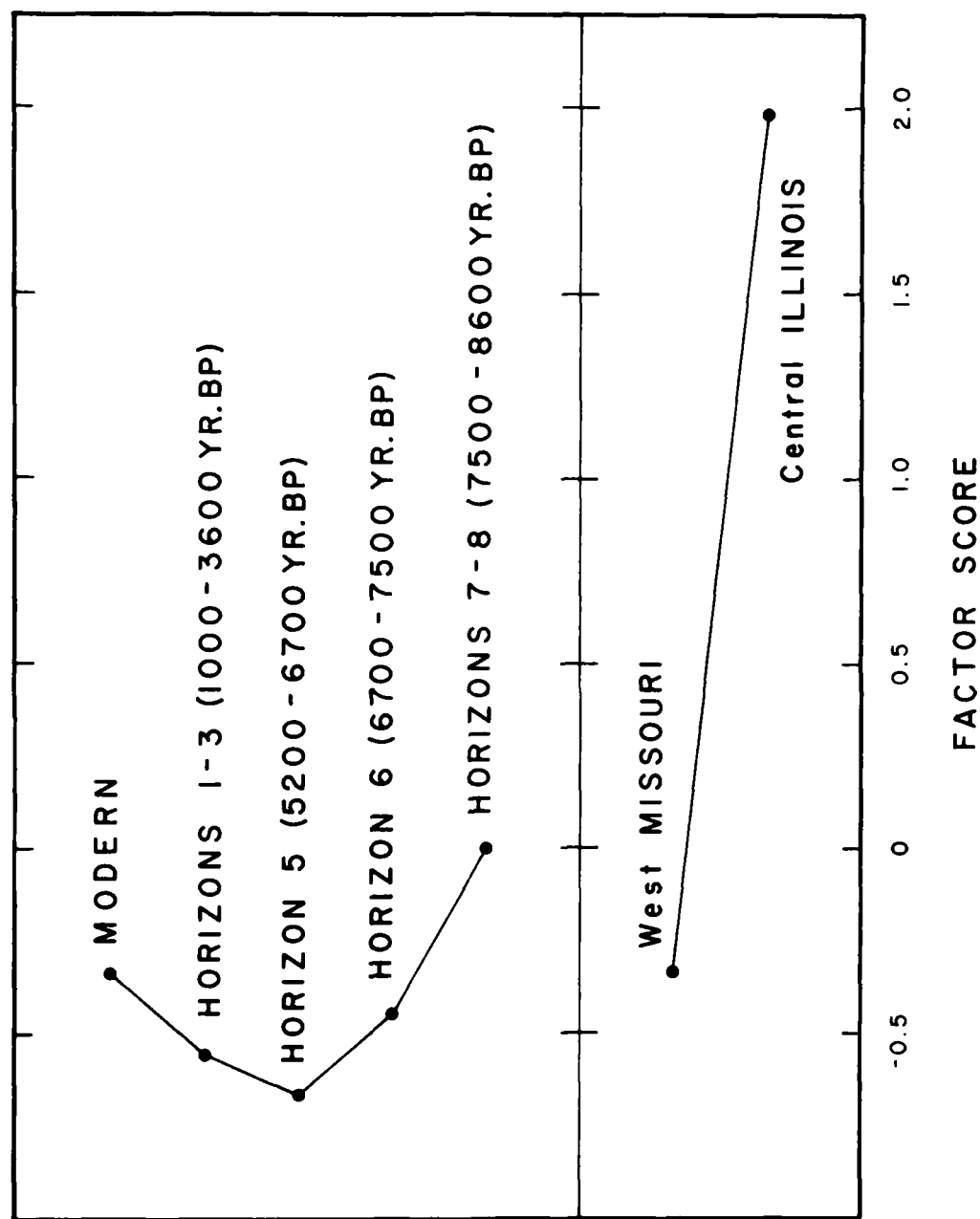


Figure 9.10. Clinal variation in modern and prehistoric eastern cottontails (*Sylvilagus floridanus*). Prehistoric specimens are from Rodgers Shelter. Data points are factor scores for Factor I (see text and Table 9.15).

TABLE 9.16

Presence and Absence of Taxa in Horizons at Rodgers Shelter

Taxon	1	2	3	4	5	6	7	8	9	10	11
Lepisosteidae	x	x	x		x	x	x	x	x		
Catostomidae	x	x	x		x	x	x	x	x	x	
<i>Notostoma</i> sp.	x	x	x	x	x	x	x	x	x	x	
Ictaluridae	x	x	x		x	x	x	x	x	x	
Centrarchidae	x	x	x		x		x	x			
<i>Aplodinotus grunniens</i>	x	x			x	x	x	x	x	x	
<i>Terrapene</i> sp.	x	x	x	x	x	x	x	x			x
Miscellaneous herptiles	x	x	x	x	x	x	x	x	x	x	
<i>Meleagris gallopavo</i>	x	x	x		x						
Miscellaneous birds	x	x	x	x	x	x	x	x		x	
<i>Didelphis virginiana</i>	x				x			x			
<i>Sceloporus aquaticus</i>	x	x	x	x	x	x	x	x	x	x	
<i>Nyctotis parva</i>	x	x			x	x	x	x			x
<i>Blarina brevicauda</i>	x	x	x		x	x	x	x	x	x	
<i>Myotis</i> sp.	x	x	x		x			x			
<i>Eptesicus fuscus</i>	x	x	x				x	x			
<i>Procyon lotor</i>	x	x	x		x	x	x	x		x	
<i>Mustela vison</i>					x			x			
<i>Spilogale putorius</i>			x		x	x	x				
<i>Mephitis mephitis</i>	x	x	x		x	x					
<i>Taxidea taxus</i>							x				
<i>Vulpes fulva</i>					x		x				
<i>Urocyon cinereoargenteus</i>					x	x					
<i>Canis</i> sp.	x	x	x		x	x	x	x			
<i>Marmota monax</i>	x	x			x						
<i>Tamias striatus</i>	x	x	x		x	x	x	x		x	
<i>Sciurus</i> sp.	x	x	x	x	x	x	x	x	x	x	
<i>Spermophilus franklini</i>	x				x	x	x				
<i>S. tridecemlineatus</i>										x	
<i>Glaucomys volans</i>						x					
<i>Peromyscus bursarius</i>	x	x	x	x	x	x	x			x	
<i>Peromyscus</i> sp.	x	x	x	x	x	x	x	x	x	x	x
<i>Neotoma floridana</i>	x	x	x	x	x	x	x	x	x	x	
<i>Castor canadensis</i>	x	x	x	x	x	x	x	x			
<i>Synaptomys cooperi</i>	x	x	x		x		x	x	x	x	x
<i>Microtus</i> sp.	x	x	x	x	x	x	x	x	x	x	x
<i>Ondatra zibethicus</i>			x		x						
<i>Sylvilagus floridanus</i>	x	x	x	x	x	x	x	x	x		
<i>Lepus virginianus</i>	x	x	x	x	x	x	x	x		x	
<i>Bison bison</i>							x				
No. of taxa	31	29	28	13	35	27	30	27	14	20	3
% of total (40)	78	72	70	32	88	68	75	68	35	50	8

patches.

To summarize, it appears that significant environmental change occurred during the Hypsithermal, but perhaps not of the magnitude implied by McMillan (1976). The meaning of this change to prehistoric human inhabitants as well as the cultural meaning of the deposition analysis will be evaluated in the summary chapter of this report.

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